CHEMISTRY

OF

ANIMAL BODIES.

BY

THOMAS THOMSON, M. D.

REGIUS PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF GLASGOW,

President of the Glasgow Philosophical Society, Fellow of the Royal Societies of London and Edinburgh, Member of the Royal Irish Academy, Fellow of the Linnean Society, Fellow of the Geological Society, Member of the Cambridge Philosophical Society, of the Cambrian Natural History Society, of the Imperial Medico-Chirurgical and Pharmaceutic Societies of St Petersburg, of the Royal Academy of Sciences of Naples, of the Mineralogical Society of Dresden, of the Cæsarean Natural History Society of Moscow, of the Literary and Philosophical and Natural History Societies of New York, of the Natural History Society of Montreal, &c. &c.

EDINBURGH:
ADAM AND CHARLES BLACK:
LONGMAN, BROWN, GREEN, & LONGMANS, LONDON.
MDCCCXLIII.

PRINTED BY JOHN STARK, EDINBURGH.

PREFACE.

The object of the present work is to lay before the British public as complete a view as I can of the present state of the Chemistry of Animal Bodies. This branch of Chemistry is much more difficult than the chemical investigation of vegetable bodies. The difficulty does not lie in the analysis; for accurate and simple methods of analyzing animal bodies as well as vegetable have been devised; but in separating the different animal bodies from each other, and obtaining each in a state of purity. These processes with respect to vegetable bodies are much facilitated by the property which they have of crystallizing. Unfortunately the most important animal substances, as albumen, fibrin, gelatin, casein, &c. want that property. The consequence is, that we have no good criterion for determining when these bodies are pure, or what the substances are with which they are mixed. The consequence of this difficulty has been, that the greater number of modern chemists have confined their investigations to those animal substances, as sugar, cholesterin, cetin, urea, &c. which are capable of crystallizing. I am not aware of any modern British chemist who has attempted to investigate any animal substance incapable of crystallizing. To Dr Wollaston we owe an

interesting set of experiments on urinary and gouty calculi; but they were made and published before the method of analyzing animal substances had been thought off. The same remark applies to Mr Hatchett's experiments on shells, bone, zoophytes, and membrane. They contain many important facts which have been overlooked by modern chemists; but at the time of the publication of these experiments, namely, 1799 and 1800, it was not to be expected that any attempt at ultimate analysis could be made.

The modern chemists to whom we are indebted for the most important analyses of animal substances, hitherto laid before the public, are Mulder and Scherer. The results of their investigations will be seen in the following work. By laying the present state of our knowledge before the reader, it is to be hoped that British chemists, when aware of the vast quantity of investigations yet requisite to place Animal on the same footing as Vegetable Chemistry, and when medical men become sensible that the farther improvement and final perfection of physiology will depend upon an accurate knowledge of the constituents and properties of animal substances, the subject will speedily draw general attention, which alone is wanting to insure a rapid advance.

CONTENTS.



CHEMISTRY OF ANIMAL BODIES.

The object of this important branch of Chemistry is to give an account of the numerous principles or definite compounds which exist in the Animal Kingdom.

When we compare animals and vegetables together, each in their most perfect state, nothing can be easier than to distinguish them from each other. The plant is confined to a particular spot, and exhibits no mark of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task; but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the most perfect classes, and consequently are in no danger of being confounded with plants. Indeed, the greater number of facts which I have to relate apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

The same arrangement which was followed in the Chemistry of Vegetable Bodies may also be applied to animal bodies. We shall first give an account of the *animal principles*, so far as their nature and constitution have been determined. In the second place, the different parts, both liquid and solid, of which the animal body is composed, will be described; and in the third place, we shall treat of those animal functions which are likely to be elucidated by chemistry.

DIVISION I.

OF ANIMAL PRINCIPLES.

The substances which have hitherto been detected in the animal kingdom, and of which the different parts of animals are supposed to be composed, may be arranged under the following heads:—

1. Animal acids.
2. Animal bases.
3. Intermediate oxides.
4. Colouring matters.
5. Amides?

These will be described in succession under their respective heads.

CLASS I.

OF ANIMAL ACIDS.

Several of these acids have been described in the *Chemistry of Inorganic Bodies*, (Vol. ii. 45.) But so much has been done by chemists since the year 1831, when that work was published, that it will be necessary to resume the account of them here, referring to the former work for every thing which does not require to be corrected or amended.

The acids derived from the animal kingdom, which have been recognized by modern chemists, and more or less accurately examined, amount to about 40. They are all compounds of two, three, four or five different constituents. The following table exhibits the composition of such of them as have been subjected to analysis:—

	Name	Formula		Atomic weight.
1.	Cyanogen, .	$C^2\ Az$	=	3·25
2.	Mesoxalic acid,	$C^3\ O^4$	=	6·25
3.	Hydrocyanic acid,	$C^2\ Az + H$	=	3·375
4.	Cyanic, .	$C^2\ Az + O$	=	4·25
5.	Formic, .	$C^2\ HO^3$	=	4·625
6.	Succinic, .	$C^4\ H^2\ O^3 + HO$	=	7·375
7.	Lactic, . .	$C^6\ H^3\ O^4$	=	8·875
8.	Butyric, .	$C^8\ H^5\ O^3$	=	9·625
9.	Suberic, . .	$C^8\ H^6\ O^3 + HO$	=	10·875
10.	Sebacic, .	$C^{10}\ H^8\ O^3$	=	11·5
11.	Choloidic, .	$C^{42}\ H^{25}\ O^6$	=	33·125
12.	Hydromellonic,	$C^6\ Az^4 + H$	=	11·625
13.	Fulminic, .	$2\ (C^2\ Az) + O^2$	=	8·5
14.	Cyanuric, .	$1\frac{1}{2}\ (C^2\ Az) + H\ 1\frac{1}{2} + O^3$	=	8·0625
15.	Cyanilic, .	$3\ (C^2\ Az) + H^3 + O^6$	=	16·125
16.	Parabanic, .	$C^6\ H^2\ Az^2\ O^6$	=	14·25
17.	Oxaluric, . .	$C^6\ H^4\ Az^2\ O^8$		16·5
18.	Pimelic, .	$C^7\ H^5\ O^3 + HO$	=	10·
19.	Adipic, . .	$C^{14}\ H^9\ O^7 + 2\ (HO)$	=	20·875
20.	Lipic, . .	$C^5\ H^3\ O^4 + HO$	=	9·25
21.	Azelaic, . .	$C^{10}\ H^8\ O^4 + HO$	=	13·625
22.	Azoleic, .	$C^{13}\ H^{13}\ O^4$	=	15·375
23.	Alloxanic, .	$C^8\ H^2\ Az^2\ O^8$	=	17·75
24.	Dialuric, . .	$C^8\ H^6\ Az^2\ O^8$	=	18·25
25.	Mycomelic, .	$C^8\ H^5\ Az^4\ O^5$	=	18·625
26.	Hippuric, . .	$C^{18}\ H^8\ Az\ O^5$	=	21·25
27.	Theionuric, .	$C^8\ H^5\ Az^3\ O^{12}\ S^2$	=	27·875
28.	Uramelic, . .	$C^{16}\ H^{10}\ Az^5\ O^{15}$	=	37
29.	Choleic, .	$C^{41}\ H^{32}\ Az\ O^{12}$	=	48.5
30.	Cholesteric, .	$C^{13}\ H^{10}\ Az^{\frac{1}{2}}\ O^6$	=	17·875
31.	Uric acid, .	$C^8\ Az^2\ O^4 + C^2\ H^4\ Az^2\ O^2$	=	21

CHAPTER I.

OF ANIMAL ACIDS DESTITUTE OF AZOTE.

These acids are twenty-two in number. The following table shows their names:—

1. Mesoxalic.	12. Lipic.
2. Formic.	13. Azelaic.
3. Succinic.	14. Azoleic.
4. Lactic.	15. Butyric.
5. Suberic.	16. Phocénic.
6. Sebacic	17. Caproic.
7. Choloidic.	18. Capric.
8. Cholic.	19. Hircic.
9. Pyrozoic.	20. Ambreic.
10. Pimelic.	21. Castoric.
11. Adipic.	22. Bombycic.

As nine of these acids have not hitherto been subjected to analysis, their constitution is unknown. It is only from analogy that they have been placed here.

SECTION I.—OF MESOXALIC ACID.

This acid was discovered by Wöhler and Liebig, and an account of it published by them in 1838.* When a saturated solution of *alloxanate*† *of barytes* is raised to the boiling temperature and allowed to cool, a precipitate falls, which is a mixture of *carbonate*, *alloxanate*, and *mesoxalate* of barytes. If we evaporate the residual liquid we obtain a crystalline crust. From this crust alcohol separates urea,‡ and leaves mesoxalate of barytes.

If we let fall drop by drop a solution of *alloxan*§ into a boiling solution of acetate of lead, a very heavy granular precipitate of *mesoxalate* of lead falls and urea remains in solution.

* Annalen der Pharmacie, xxvi. 298.

† This acid will be described in a subsequent section. It is one of the acids containing azote.

‡ An animal oxide which will be described in a subsequent part of this work.

§ Another animal oxide to be described afterwards.

This salt of lead may be decomposed by adding the quantity of sulphuric acid just requisite to saturate the oxide of lead. Or we may separate the lead by passing a current of sulphuretted hydrogen gas through water with which the mesoxalate of lead has been mixed. If we filter to get rid of the lead, and apply heat to drive off what sulphuretted hydrogen may exist in the liquid, we obtain a solution of mesoxalic acid in water.

Mesoxalic acid crystallizes readily, though the shape of the crystals has not been determined. Its reaction is strongly acid, and it is very soluble in water. With the salts of lime and barytes it gives precipitates, but only after the addition of ammonia. It does not give oxalic acid when evaporated or boiled in an open vessel. Its distinguishing characteristic is to form with the salts of silver, after the addition of a little ammonia, a yellow precipitate, which, on exposure to a gentle heat, is reduced to the metallic state, while a great deal of carbonic acid gas is given off.

When mesoxalate of lead is heated with a little nitric acid, it is converted into oxalate of lead, while, at the same time, nitrous gas is given out, showing that oxygen has been added to the acid of the salt.

When alloxanate of silver is dissolved in boiling water, it does not change colour, but if we add a little ammonia, it becomes yellow, and if the boiling be prolonged, it becomes all at once black, while a lively effervescence takes place. The alloxanate of silver in this case is decomposed into mesoxalate, to which that kind of reaction is peculiar.

Liebig analyzed the mesoxalate of lead, and obtained

Carbon, .	6·85
Hydrogen, .	0·20
Oxygen, .	12·21
Oxide of lead, .	80·74
	100·00

The quantity of hydrogen is so small, that he was of opinion that the acid in reality contains none. In that case it is a compound of carbon and oxygen only, like oxalic acid. If the oxide of lead in the salt amount to two atoms, then the atomic weight of the mesoxalic acid will be 6·67. For 80·74 : 19·26 :: 28 : 6·67. Now the numbers that accord best with the analysis and with this atomic weight are the following:

3 atoms carbon,	= 2·25,	or per cent.	6·57
4 atoms oxygen,	= 4·00,	...	11·67
2 atoms oxide of lead,	= 28.00,	...	81·76
			100·00

This would make mesoxalic acid $C^3 O^4$ = 6·25, or it is equivalent to two atoms carbonic acid, together with an additional atom of carbon. Admitting this composition to be correct, we have no fewer than five acids composed of carbon and oxygen, namely,

Croconic,	.	$C^5 O^4$
Mesoxalic,	.	$C^3 O^4$
Oxalic,	.	$C^2 O^3$
Rhodizonic,	.	$C^3 O^5$
Carbonic,	.	$C\ O^2$

Liebig is of opinion that the want of exact accordance between the analytical and theoretical numbers in the above analysis was owing to the presence of a little *cyanate* or *cyanurate* of lead in the mesoxalate subjected to analysis. This, however, can only be considered as a plausible explanation. Additional experiments are still wanting to decide the point completely. Meanwhile, if we admit the constituents of mesoxalic acid to be as above stated, it is easy to explain the conversion of mesoxalate of silver by heat into metallic silver and carbonic acid. Mesoxalate of silver must be a compound of

1 atom mesoxalic acid,	.	$= C^3 O^4$
2 atoms oxide of silver,	.	$= 2 (Ag\ O)$

By heat the two atoms of oxygen leave the silver and combine with the mesoxalic acid. We have consequently $C^3 O^6 + 2$ Ag. but $C^3 O^6$ is equivalent to three atoms of carbonic acid.

When a solution of alloxanate of barytes is boiled, it undergoes decomposition. A white precipitate falls, which is a mixture of mesoxalate, alloxanate, and carbonate of barytes. When calcined, it gives out a notable quantity of hydrocyanic acid and effervesces feebly with acids. When the liquid separated from this precipitate is evaporated, it gives a yellow foliated mass of mesoxalate of barytes, which may be purified by washing it with alcohol. When this salt was heated with oxide of copper, it gave no trace of azote; 100 parts of it gave 72·1 of carbonate of ba-

rytes, equivalent to 55·91 of barytes. From this analysis, Liebig concludes that the salt was composed of

1 atom mesoxalic acid,	6·25,	or per cent.	37·04
1 atom barytes,	9·5,	...	56·30
1 atom water,	1·125,	...	6·66
	16·875		100·00

It is easy to see how mesoxalic acid results from the decomposition of alloxânic acid.

Hydrous alloxanic acid is	$C^8 H^4 Az^2 O^{10}$
Subtract 1 atom urea,	$C^2 H^4 Az^2 O^2$
Remain 2 atoms mesoxalic acid,	$C^6 \quad O^8$

SECTION II.—OF FORMIC ACID.

An account of this acid has been given in the *Chemistry of Inorganic Bodies*, ii. 58, and *the Chemistry of Vegetables*, p. 17.

It is secreted by the *Formica rufa* or red ant, and is the liquid that renders the bites of these insects so painful. It was first publicly noticed by Mr Ray in the year 1670.* Dr Hulse had written him that he had found this passage in *Langham's Garden of Health*, "Cast the flowers of *cichory* (*Cichorium Intybus*) among a heap of ants, and they will soon become as red as blood." He mentions that the fact had been observed before by various individuals, among others by John Bohin. Dr Hulse said that he had tried the experiment and found it to succeed. Mr Fisher had stated to Mr Ray several years before, that, "if you stir a heap of ants so as to rouse them, they will let fall on the instrument you use a liquor which, if you presently smell to, will twinge the nose like newly distilled oil of vitriol." Mr Fisher farther stated, that, "when ants are distilled by themselves or with water, they yield a spirit like spirit of vinegar, or rather like spirit of *viride æris*." It dissolves lead and iron. When you put the animals into water, you must stir them to make them angry, and then they will spirt out their acid juice." Margraaf obtained this acid in 1749, by distilling ants mixed with water and rectifying the liquid which came over. The acid obtained had a sour taste and smell. It combined with potash and ammonia, and formed crystallizable salts with both. It did not precipitate nitrates of

* Phil. Trans. v. 2063, or Abridgement, i. 554

lead, silver, or mercury, nor chloride of calcium. It did not attack silver, but dissolved its oxide. It did not dissolve red oxide of mercury, but when digested with it, the mercury was reduced to the *metallic state*. It did not attack copper, but dissolved its oxide, and formed with it beautiful green crystals. It dissolved iron filings, and yielded small crystals. This, he says, is worthy of remark, because the solution of iron in distilled vinegar does not crystallize. It did not attack lead, but readily dissolved red lead, and formed beautiful crystals similar to those of acetate of lead. It dissolved zinc, and yielded crystals quite different from those of acetate of zinc. It scarcely acted on bismuth or antimony or their oxides. It dissolved carbonate of lime with rapidity, and formed with it a crystalline mass.*

In 1781, Arvidson confirmed the observations of Margraaf, and gave ample details respecting the preparation and concentration of this acid.† In 1782, Bucholz showed how it might be obtained in a very concentrated state by forming dry formate of potash, mixing the dry salt with the requisite quantity of sulphuric acid and distilling. He formed also a small quantity of formic ether.‡ In 1784, Hermbstadt published an elaborate paper on the preparation of this acid, but did not add much to what was already known.§ Richter followed in 1793, and proceeded nearly as Bucholz had done.‖ Deyeux started the notion that formic was identical with acetic acid, and this was followed up by a set of experiments by Fourcroy and Vauquelin, from which they concluded that it was a mixture of acetic and malic acids.¶ This opinion was called in question by Suerzen, who demonstrated that pure formic acid contains no malic acid, and that its properties were different from those of acetic acid.** This indeed had been already proved by Margraaf; but the French chemists had paid no attention to his experiments. Gehlen resumed the subject in 1812, and showed, in the most convincing manner, that formic and acetic acids possess different characters.††

Dobereiner discovered a method of preparing formic acid artificially by mixing tartaric acid and binoxide of manganese in a

* Opuscules Chymiques de M. Margraaf, i. 301.
† Wieglib's Geschichte, ii. 242. ‡ Ibid. ii. 269.
§ Crell's Annalen, 1784, ii. 209.
‖ Ueber die neueren Gegenstände der Chemie, vi. 135.
¶ Phil. Mag. xv. 118. ** Gehlen's Jour. iv. 3.
†† Schweigger's Jour. iv. 1.

still, and pouring over the mixture sulphuric acid, diluted with water. An effervescence takes place, and formic acid may be distilled over. Wöhler and Liebig have shown that sugar, starch, &c. may be substituted for tartaric acid. But, as the preparation of this acid has been minutely described in the *Chemistry of Vegetable Bodies*, (p. 17), the reader is referred to that work.

The characteristic property of formic acid is this: When formic acid or formate of soda is put into a solution of any salt of gold, platinum, or silver, an effervescence takes place, and the gold, platinum, or silver is deposited in the metallic state. It effervesces also, and reduces to the metallic state oxide of silver and oxide of mercury.

This acid has been shown to consist of $C^2HO^3 = 4.625$. It differs from oxalic acid by containing an atom of hydrogen, while oxalic acid is $C^2 O^3 = 4.5$.

SECTION III.—OF SUCCINIC ACID.

This acid has been known for nearly a century. The mode of obtaining it, together with its properties and constitution, has been given in the *Chemistry of Inorganic Bodies*, (Vol. ii. p. 89.) A curious discovery made by M. Bromeis during the course of the winter 1839–40, makes it necessary to introduce it here. He found that when nitric acid is made to act upon stearic acid, one of the products obtained is succinic acid.* When the nitric acid solution formed is evaporated to one-half, it concretes in twenty-four hours to nearly a solid mass, which, when put into a glass funnel, and washed with cold water, is freed from the mother ley. When these washings are concentrated, they yield a white firm crystalline salt; which Bromeis found to be succinic acid composed of $C^4 H^2 O^3 + HO$, and agreeing in all its properties with succinic acid from amber.

SECTION IV.—OF LACTIC ACID.

This acid is formed when milk becomes *sour*. It was first examined by Scheele, who pointed out its most remarkable properties, and noticed its analogy to acetic acid.† He called it *milk acid*, which was afterwards converted into *lactic acid*, as more

* Annalen der Pharmacie, xxxv. 90.

† Kong. Vet. Acad. Handl. 1780, p. 116, or Scheele's Essays, p. 273.

suitable to the English language. The French chemists endeavoured to prove that lactic acid is merely the acetic, holding some animal matter in solution. But this opinion was refuted by Berzelius. It was afterwards observed that lactic acid is formed when various vegetable substances are allowed to get sour, particularly when oatmeal is left in a considerable quantity of water.

The constitution and properties of lactic acid were fully investigated by MM. Jules Gay-Lussac and Pelouze. A full account of the facts which they ascertained has been given in the *Chemistry of Vegetable Bodies*, (p. 22). The reader is therefore referred to that work. It has been shown by these chemists that the atomic weight of lactic acid is 9, and that its constitution is $C^6 H^4 O^9$.

MM. Fremy and Boutron-Charlard have ascertained that all animal substances which act as ordinary ferments have the property of gradually converting sugar, dextrin, gums, starch, &c. into lactic acid. The process is stopped by a heat of 212°. Their observations have led them to the following method of preparing lactic acid:—Put malt, slightly moistened, for a few days into a stoppered bottle. The animal matter contained in the malt undergoes a modification; the temperature rises, and if we keep this modified malt for two or three days in water of the temperature of 104°, that water becomes strongly acid, and contains a notable quantity of lactic acid. *

They have found that animal membranes (bladder for example) after being dried and kept in moist air till it begins to undergo decomposition, has the property of converting a solution of sugar into lactic acid. When milk becomes sour lactic acid is generated by the action of the casein on the sugar of milk. The casein combines with lactic acid, and becomes insoluble, which stops the process. But if we saturate the lactic acid formed with bicarbonate of soda, the casein becomes again soluble, and acting on the sugar of milk a new portion of lactic acid is formed. This process of neutralization may be repeated till the whole sugar of milk is converted into lactic acid. †

MM. Cap and Henry have discovered that the urea in urine is in the state of lactate of urea. They have made some observations on the lactates which deserve to be stated ‡

* Jour. de Pharm. xxvi. 477. † Ibid. xxvii. 325.
‡ Ibid. xxv. 133.

Lactate of zinc crystallizes in fine needles. Its taste is acid and styptic. It is more soluble in hot than in cold water. It is scarcely soluble in alcohol, and is precipitated in white flocks by the alkaline sulphurets.

Lactate of lime forms small white crystals, which feel gritty between the teeth. It has a bitterish taste. When heated it melts and assumes the aspect of a resin. It is more soluble in hot than in cold water. When heated with sulphuric acid there is a slight effervescence, and the mixture becomes black, and gives out the smell of apples.

Lactate of barytes does not crystallize, but assumes the aspect of gum. It is very soluble in water and alcohol.

When lactic acid is treated with peroxide of lead, or deutoxide of barytes, it is converted in a great measure into oxalic acid. When chlorites or chlorous acid are used, the decomposition is rapid. Oxalates are formed, which continue only for a very short time, the effervescence showing the evolution of carbonic acid.

Lactic acid, even when dilute, rapidly dissolves most phosphates of lime; oxalate of lime also is to a certain extent soluble in the same acid.

SECTION V.—OF SUBERIC ACID.

Chevreul states that when oleic, stearic, or margaric acid is boiled with 100 times its weight of concentrated nitric acid, till the whole oily acids disappear, we obtain on evaporation a mixture of an insoluble oily acid, and another acid soluble in twenty times its weight of water.* M. Laurent repeated the experiments of Chevreul, and obtained the same acid substance. He found it a mixture of several different acids; but the one which existed in greatest abundance was *suberic acid*.† M. Brömeis confirmed this curious discovery of Laurent, and analysed the suberic acid with great care.‡

If we evaporate the nitric acid solution to one-half it concretes in twenty-four hours to a mass nearly solid. This mass is put into a glass funnel, and washed with cold water to free it from the mother ley. After being three times crystallized from warm water, exposed to pressure and dried, suberic acid is obtained in a state of purity.

* Sur les corps gras, p. 28. † Ann. de Chim. et de Phys. lxvi. 157.
‡ Annalen der Pharm. xxxv. 89.

Suberic acid thus obtained melts at 248, and congeals into a mass consisting of clear, fine, pointed needles. When heated in a small glass flask, it generates a vapour highly impeding respiration, which collects into drops and congeals into crystals, leaving behind it a charry residue. The free acid precipitates acetate of lead, and the precipitate is insoluble in water and in alcohol. Suberate of ammonia precipitates solutions of chlorides of calcium, strontium, and barium upon the addition of alcohol. It precipitates also the neutral salts of silver, mercury, zinc, and tin, white. The last precipitate is readily soluble in alochol. Sulphate of copper is precipitated bluish green, and persulphate of iron brownish red.

Bromeis found suberate of silver composed of

Suberic acid, . . .	42·1	or 10·543
Oxide of silver, . . .	57·9	or 14·5
	100·0	

Neutral suberate of lead was composed of

Suberic acid, . .	42·38	or 10·297
Oxide of lead, . . .	57·62	or 14·
	100·00	

Disuberate of lead

Suberic acid,	19·58	or 10·228
Oxide of lead,	80·42	or 28·
	100·00	

Suberate of soda

Suberic acid, . .	70·62	or 9·62
Soda, . . .	29·38	or 4·
	100·00	

Suberate of ethyloxide

Suberic acid, .	9·75
Ether, . . .	4·625

Hydrated suberic acid being analysed with oxide of copper, was composed of $C^8 H^6 O^3 + HO = 10{\cdot}875$; so that the anhydrous acid has an atomic weight of 9·75.

SECTION VI.—OF SEBACIC ACID.

Though sebacic acid is obtained during the distillation of tal-

low, and is therefore an animal product; yet its characters are so similar to the acids belonging to the vegetable kingdom, that it was thought requisite to place it among them. Accordingly it has been described in the *Chemistry of Vegetable Bodies* (p. 31,) to which work the reader is referred. It has been shown by Dumas and Peligot that the atomic weight of this acid is 11.5. and that its components are C^{10} H^{8} O^{3}.

SECTION VII.—OF CHOLOIDIC ACID.

This acid was discovered by M. Demarçay in the year 1838.* The process which he employed to obtain it was the following:— Dissolve *ox bile* in twelve or fifteen times its weight of water, and boil it with an excess of muriatic acid for three or four hours, and then let it cool. The choloidic acid will be found collected at the bottom of the vessel in a solid mass. Decant off the liquid portion, and melt the acid by heat three or four times successively in small quantities of distilled water. Finally, dissolve the acid in alcohol, and agitate the solution with a little ether to dissolve out any *cholesterin* and *margaric acid* that it may contain. After this treatment, if the solution be evaporated to dryness over the water bath, there will remain choloidic acid nearly pure, but still retaining a trace of common salt.

Choloidic acid thus obtained is a solid fatty looking substance, of a yellow colour, destitute of smell, and having a very bitter taste. It does not melt till heated above 212.° While solid, it is brittle and easily reduced to powder. When heated in boiling water, it melts into a brown, pasty magma. It is very soluble in alcohol, even when weak, but little soluble in water, and scarcely at all in ether.

The solutions of this acid strongly redden litmus-paper, and decompose the carbonates with effervescence. The choloidates thus formed are little soluble in water, and even in alcohol; but they are neutral. Acids throw it down from these compounds in yellow flocks, which unite when heated and liquefy.

The choloidates of zinc, manganese, iron, lead, copper, and silver are flocky precipitates, which, when cautiously heated, become granular, and melt at about 176°. They are all slightly soluble in water.

Demarçay attempted to analyse the choloidates of lead, barytes,

* Ann. de Chim. et de Phys. lxvii. 198.

copper, and silver; but could not succeed in obtaining these salts constant in their composition. Water decomposes them into super and subsalts. Hence it happens that, when we obtain the choloidates by precipitation, the proportion of acid in them varies with the concentration of the liquid, and when we attempt to wash them. The consequence of this is, that the atomic weight of this acid is still unknown.

Demarçay made three ultimate analyses of it by means of oxide of copper, and obtained as a means of the three,

Carbon,	.	72·46
Hydrogen,	.	9·57
Oxygen,	.	17·97
		100·00

Now, it will be shown in a subsequent section that ox bile is a compound of *choleic* acid and soda, and that choleic acid is composed of $C^{42}\ H^{36}\ Az\ O^{12}$. When bile is boiled with muriatic acid, besides choloidic acid there is another substance formed, which L. Gmelin, the discoverer, distinguished by the name of *taurin*. This substance, which will be described in a subsequent chapter of this volume, was analysed by Demarçay, and found composed of $C^4\ H^7\ Az\ O^{10}$.

Now, if from choleic acid, . . .	$C^{42}\ H^{36}\ Az\ O^{12}$
We subtract taurin, . .	$C^4\ H^7\ Az\ O^{10}$
And to the remainder, .	$C^{38}\ H^{29}\ O^2$
Add four atoms water, .	$H^4\ O^4$
We get, . . .	$C^{38}\ H^{33}\ O^6$

Now this approaches somewhat the constitution of choloidic acid.

For 37 atoms carbon,	=	27·75 or per cent.	74
30 atoms hydrogen,	=	3·75	10
6 atoms oxygen,	=	6·00	16
		37·50	100

But this formula differs too much from the analysis to be confided in. And Demarçay ascertained that the atomic weight of choloidic acid was not 37.5. The number of atoms that would suit the analysis would be—

32 atoms carbon,	= 24·	or per cent.	72·45
25 atoms hydrogen,	= 3·125		9·43
6 atoms oxygen,	= 6·		18·12
	33·125		100·00

But these atomic constituents differ from those of Demarçay by five atoms of CH.

SECTION VIII.—OF CHOLIC ACID.

It has been already mentioned in the last section that bile is a compound of choleic acid and soda. Now, when we boil bile with a fixed alkali, the choleic acid is changed into *cholic acid.* But it is not easy in this way to obtain cholic acid in any quantity. The most convenient method, according to Demarçay, who discovered this acid, is the following.*

Boil in a capsule equal parts of bile and caustic potash dissolved in twice its weight of water, adding just water enough to keep the mixture liquid. This boiling process should be continued for some days. The brown clots, which separate by the evaporation of the alkaline liquid, are removed, drained, washed on the filter, and dissolved in water. Acetic acid precipitates from the solution white flocks, which collect on the surface, forming a solid crust, spongy and very friable, if most of the choleic acid has been decomposed; but if not, the flocks are brown and pitchy, and require to be again treated with potash.

The precipitate is thrown on a filter, washed, dissolved in alcohol, and the solution left to spontaneous evaporation. White acicular crystals gradually appear on the surface. They are to be separated by decantation, and washed in cold alcohol. By degrees, the liquid separates into two layers; the undermost of which has the colour of cashew nut, and is thick and viscid. It is a mixture of choleic and cholic acids. The uppermost is clear and transparent. It is a dilute solution of the two acids. This mixture of the two acids must be again boiled with potash as before.

The crystals must be dissolved in hot alcohol. By evaporation, the acid separates in tetrahedrons. It may be rendered pure by two or three crystallizations from alcoholic solutions.

The crystals of cholic acid are at first transparent and colour-

* Ann. de Chim. et de Phys. lxvii. 200.

less, but by exposure to the air they become opaque. Yet the silky crystals deposited from boiling alcohol retain their limpidity and their other characters.

The taste of cholic acid is bitter but weaker than that of bile. It is very soluble in alcohol and ether; but insoluble in water. The solution reddens litmus paper, decomposes the carbonates with effervescence, and neutralizes bases. When the etherial solution is rapidly evaporated, it leaves a deposit having a greasy feel, showing that the acid belongs to the tribe of oily acids.

It is fixed, burning with flame, giving out smoke, and leaving a good deal of charcoal.

The characters of the *cholates* are quite different from those of the *choleates* and *choloidates*. They have not a resinous consistence, do not melt in boiling water and dry easily. It is difficult to obtain them quite neutral.

The cholates of potash and soda are soluble in water, while the cholates of lime, barytes, zinc, copper, and silver are insoluble in that liquid. They are readily decomposed into bisalts and disalts.

SECTION IX.—OF PYROZOIC ACID.

This name was applied by Berzelius to an acid formed when animal substances are distilled *per se*. Unverdorben,* who first examined its properties, distinguished it by the name of *brandsaüre*.

When an animal substance, glue, muscle, &c. is distilled *per se*, the first product is carbonate of ammonia, partly dry and partly dissolved in a brown-coloured liquid, which contains a variety of substances besides. The second product is an empyreumatic oil; which is generally called Dippel's oil; because it was Dippel who first obtained it in a state of purity. This oil in its crude state has a yellow or rather brown colour, and contains a variety of bases, which will be described in a subsequent part of this volume. The empyreumatic oil is mixed with potash and distilled. The pyrozoic acid remains in combination with the potash. The potash residue is diluted with water and evaporated. And this process is repeated several times to get rid of all the empyreumatic oil which it contains. As soon as the smell of empyreumatic oil can no longer be perceived, dilute sulphuric acid is added to the alkaline liquor as long as a matter similar to *tar* continues to precipitate. It is

* Poggendorf's Annalen, viii. 262.

then distilled in a retort, and when it begins to get thick, new portions of water are added, and the distillation is continued till no more volatile oil passes into the receiver along with the vapour of water. It is this volatile oil which constitutes the *pyrozoic acid.*

It is a limpid liquid of a pale yellow colour, and has a sharp and empyreumatic smell. According to Unverdorben, it is to the presence of this acid that the empyreumatic oils owe their peculiar odour. Its vapours redden litmus paper. It is insoluble in water; but very soluble in alcohol, ether, and the volatile oils. In the dilute acids it does not dissolve. It ought to be kept in well stopped phials, which should be filled with it, because when in contact with the air, it is speedily decomposed, becoming brown, and then black and thick.

It is a very feeble acid, being incapable of decomposing the alkaline carbonates, even when assisted by heat. Its salts crystallize with difficulty. When exposed to the air, they gradually undergo decomposition, a *resin* being deposited, and, if we believe Unverdorben, a butyrate of the base remains.

Pyrozoate of potash is formed by dissolving the acid to saturation in caustic potash ley. If, during the evaporation, we add an excess of acid, we obtain at first a syrup, then minute crystals, and finally, a dry white mass, split in all directions. This mass bears a strong heat, without decomposition; but it becomes at last black, and then, according to Unverdorben, water extracts from it butyrate of potash.

Pyrozoate of lime is soluble in fifteen times its weight of water. When the solution is evaporated, the salt separates partly as a pellicle and partly as a powder.

Pyrozoate of copper may be formed by double decomposition. It is a light green powder. It is slightly soluble in water, communicating to that liquid a green tint. It is more soluble in alcohol, ether, and the fixed and volatile oils. The alkalies partly decompose it, leaving a brown-coloured subsalt. When distilled *per se* it gives off about half the acid, which it contains, unaltered. It gives off also *oderin*, a little butyric acid, and a brownish-coloured substance soluble in potash.

Pyrozoic acid combines also with *fuscin*, forming a brown insoluble compound, from which potash extracts the acid, leaving the fuscin.

SECTION X.—OF PIMELIC ACID.

This acid was discovered by Laurent, and was one of the numerous products obtained when oleic acid is heated with concentrated nitric acid.* Bromeis got it in the same way, and subjected it to a rigid analysis.†

It is found most abundantly in the water employed to wash the suberic acid, obtained from oleic acid by the process described in a former section. It exists also in smaller quantity in the mother ley from which the suberic acid had precipitated, and may be obtained by slow evaporation. After being repeatedly crystallized from water to free it from two very soluble acids, which will be described in the two following sections, it forms a mass, differing in appearance from suberic acid, and consisting of single white, small grains. After having been dried in a heat of 212° it melts at 273°, and may be easily sublimed in fine, silky, feather-shaped crystals. It is rather more soluble in water than suberic acid. Pimelate of ammonia does not precipitate chlorides of barium, strontium, calcium, manganese, and zinc, nor sulphate of copper.

It has no smell but a much stronger acid taste than suberic acid has. It is not altered by exposure to the air. It is very soluble in boiling water. At 64½° one part of it is soluble in 35 of water. Alcohol, ether, and sulphuric acid dissolve it readily when assisted by heat.

It was analyzed with nearly the same result by Laurent and by Bromeis. The last mentioned chemist found pimelate of silver composed of

Pimelic acid, .	37·75 or 87·37	
Oxide of silver,	62·25 or 14·5	
	100·00	

When analyzed by means of oxide of copper, the hydrous acid gave Laurent

Carbon, .	52·52
Hydrogen, .	7·50
Oxygen, .	39·98
	100·00

* Ann. de Chim. et de Phys. lxvi. 163. † Annalen der Pharm. xxxv. 104.

Bromeis obtained

Carbon,	49·56
Hydrogen,	7·06.
Oxygen,	43·38
	100·00

And the analysis of the pimelate of silver gave him

Carbon,	21·98
Hydrogen,	2·64
Oxygen,	13·13
Oxide of silver,	62·25
	100.

From these analyses the following formula may be deduced, $C^7 H^5 O^3 + HO = 10$. For

7 atoms carbon	5·25	or per cent.	52·5
6 atoms hydrogen	= 0·75		7.5
4 atoms oxygen	= 4·00		40·0
	10·00		100·

SECTION XI.—OF ADIPIC ACID.

This acid, like the preceding, was discovered by Laurent.* The mother water from which the pimelic acid had been obtained was freed as much as possible from nitric acid by evaporation, taking care not to evaporate too far, otherwise the whole mass is decomposed violently and becomes black. We must therefore, after a cautious evaporation, let the solution crystallize for two or three days. Draw off the liquid portion by a sucker, and wash the crystals with a little cold water. These evaporations and crystallizations must be repeated till the liquid ceases to deposit any more crystals. The crystals are dissolved in water and again crystallized. They constitute a mixture of *adipic* and *lipic* acids. To separate them, the crystals are dried and then dissolved in ether by the assistance of heat. The solution is left to spontaneous evaporation till it is reduced to one-half. The portion remaining liquid is decanted off the crystals deposited and evaporated. The two products thus obtained from

* Ann. de Chim. et de Phys. lxvi. 166.

the ether are dissolved separately in boiling alcohol, and the solutions are left to spontaneous evaporation. These solutions and crystallizations are repeated two or three times. Two sets of crystals are obtained. The one in groups of round tubercles is the *adipic* acid; the other in elongated plates is the *lipic* acid.

Adipic acid thus obtained is in tubercles composed of needles radiating from a centre. Laurent always obtained it of a brown colour, which enabled him to distinguish it from pimelic acid, which is white. The spherules of which it is composed are softer and longer than those of pimelic acid. After being dried at 212°, it melts when heated to 293°, and, like pimelic acid, it may be readily sublimed in beautiful crystals. It is almost equally soluble in ether, water, and nitric acid.

Adipate of ammonia crystallizes in needles. It does not precipitate chlorides of barium, strontium, and calcium, nor sulphates of magnesia, manganese, nickel, cobalt, and copper; nor acetate of lead. It precipitates perchloride of iron brick-red. When nitrate of silver is dropt into adipate of ammonia, no precipitate appears at first; but when a sufficient quantity of nitrate has been added, a white precipitate falls.

M. Bromeis analyzed adipate of silver, and found it composed of

Adipic acid,	.	39·39 or 18·846
Oxide of silver,		60·61 or 29.
		100·00

The adipate of barytes was composed of

Adipic acid,	.	48·58 or 17·95
Barytes,	. .	51·42 or 19.
		100·00

Bromeis found the constitution of the hydrous acid to be

Carbon,	.	49·56
Hydrogen,	.	7.06
Oxygen,	.	43·38
		100·

The analysis of adipate of silver agreed with this; only that there were two atoms of water in the acid. They had been displaced by the oxide of silver. Now, the formula that accords

best with this analysis, and with the atomic weight of the anhydrous acid, as it exists in adipate of silver, is $C^{14} H^{9} O^{7} + 2 (HO) = 20{\cdot}875$.

14 atoms carbon,	= 10·5	or per cent.	50·30
11 atoms hydrogen,	= 1·375	...	6·58
9 atoms oxygen,	= 9·0	...	43·12
	20·875		100·

SECTION XII.—OF LIPIC ACID.

This acid is contained in the thick brown mother ley separated from pimelic acid, as mentioned in the 10th section of this chapter. When this liquid is farther evaporated, and left for some time at rest, the lipic acid separates in large transparent crystals as mentioned in the last section.

The crystals are oblique elongated plates, usually grouped together. This acid is much more soluble in cold water than either of the two preceding acids. It dissolves readily in alcohol and ether. When heated in a retort, it may be distilled over without alteration. When slowly heated, it sublimes in long needles. When the temperature is raised cautiously, it gives out water, and an anhydrous acid remains which melts between 284° and 293°. Its vapour excites coughing, and is very suffocating.

Lipate of ammonia crystallizes in long prisms. When mixed with a solution of chloride of barium, nothing happens at first; but in a few minutes crystals of lipate of barytes are deposited. They are square prisms passing into octahedrons. In twenty-four hours hardly any lipate of barytes remains in solution.

Chloride of calcium behaves nearly as chloride of barium. Chloride of strontium gives a kind of coronet.

When the dry lipates are heated with sulphuric acid, lipic acid is disengaged in needles.

Lipate of ammonia does not precipitate the salts of manganese nor of magnesia. It precipitates the salts of iron, copper, and silver. According to the analysis of Laurent, to whom we are indebted for everything known of this acid, its constitution may be represented by this formula, $C^{5} H^{3} O^{4} + HO = 9{\cdot}25$.

SECTION XIII.—OF AZELAIC ACID.

This acid, like the three preceding, was discovered by Laurent; but he procured it only in small quantity, and probably not pure. It was obtained, like the preceding, from the liquid formed by digesting oleic acid in nitric acid. The suberic acid, obtained by the method described in a former section, was agitated with ether, which dissolved the azelaic acid. The ether was evaporated, and the residue left in contact with cold ether, and this ether was again evaporated. This process was repeated. What remained was azoleic acid. It constituted an opaque mass, in which small radiated spheres may with difficulty be distinguished.

Azelate of ammonia does not precipitate chlorides of barium, strontium and magnesium, not even though alcohol be poured into the mixture. Concentrated chloride of calcium gives a precipitate; but if that salt be dilute, no precipitation takes place. The salts of lead, silver, and mercury are precipitated white. According to the analysis of Laurent, the constitution of this acid is represented by this formula, $C^{10} H^{8} O^{4} + H O = 13{\cdot}625$.*

SECTION XIV.—OF AZOLEIC ACID.

This acid was also discovered by Laurent, and is one of the products of the action of nitric acid on oleic acid. It was obtained from the oil swimming on the surface of the nitric acid, which amounted to about a fifth of the oil originally employed.

This oil was converted into an ether by mixing it with alcohol and sulphuric acid, and distilling off a certain portion. If we distil the whole, the ether is decomposed. The ether was decomposed by an alcoholic solution of potash. The potash being now neutralized by muriatic acid, the azoleic acid separated. It is liquid and insoluble in water. Laurent analyzed it, (supposing it to contain four atoms oxygen,) and gives the following formula for its constitution: $C^{13} H^{13} O^{4} = 15{\cdot}375$.†

This acid has been but very imperfectly examined. M. Bromeis has promised us a set of experiments on it and the azelaic acid.

SECTION XV.—OF LITHOFELLIC ACID.

This acid was discovered by M. Goebel‡ of Dorpat, in a sup-

* Laurent, Ann. de Chim. et de Phys. lxvi. 172. † Ibid. 173.
‡ Ann. der Pharm. xxxix. 237.

posed gall-stone in the zoological cabinet of that place, labelled, *a gall-stone consisting of concentric layers.* There was no account of its origin or history. It was oval, had a nucleus of albumen coloured by bile, weighed 240 grains, and had a specific gravity of 1·043 at the temperature of 68°. It was insoluble in water, muriatic acid, and acetic acid; slightly soluble in ether, and readily soluble in boiling alcohol, with the exception of a little albumen coloured greenish-brown by bile. From this solution it crystallized in hard pulverizable crystals, which Wöhler found to be short six-sided prisms.

When heated in a platinum spoon it melted into a yellow liquid, which caught fire when the heat was raised, leaving a small quantity of shining charcoal, which gradually burnt away without leaving any residue.

When heated with nitric acid it frothed strongly and the acid was partly decomposed, then it dissolved in the surplus acid. The solution being evaporated left a beautiful lemon-yellow mass insoluble in water; but when rubbed or heated in that liquid it assumed the appearance of a white resin.

When heated with potash ley it is saponified, giving out the smell of ambergris. From this soap acids throw down a yellowish white powder, identical with the crystals from the alcoholic solutions, and constituting a new acid, to which Goebel has given the name of *lithofellic* acid.

To obtain this acid the concretion was dissolved in boiling alcohol of 99 per cent, and the greenish brown filtered liquid slowly evaporated. The acid was deposited in crystals coloured greenish yellow by bile. They were pulverized and washed with cold alcohol to remove the colouring matter, and again dissolved in boiling alcohol and crystallized. They were now nearly colourless. The crystals were oblique prisms with oblique terminations.

At 68° it dissolves in 29·4 times its weight of alcohol, and in six and a-half times its bulk of boiling alcohol; 44·4 parts of ether were required at 68°, and 47 parts of boiling ether to dissolve one of the acid.

The melting point of the crystallized acid is 401°. At that temperature, if allowed to cool, it becomes solid, assumes a crystalline appearance, and becomes opaque. But if the temperature be

raised a few degrees above 401°; it assumes on cooling the form of a transparent vitreous, brittle matter, which becomes electric when rubbed. In this state it fuses at 221°. It is not the least crystalline, but when a little alcohol is poured on it many cracks appear, which have a certain regularity, and even under a thin layer of alcohol it is speedily converted into a mass of crystals.

When heated in a retort a white vapour was given out, which condensed into a yellowish liquid, and there passed over into the receiver a mixture of empyreumatic oil and acid water. The oil had a penetrating smell similar to that of oil of amber. A small quantity of charcoal remained in the retort. The product of distillation seemed to contain a new acid. It formed with potash a soap, which, when decomposed by muriatic acid, was analogous to the empyreumatic oil employed.

When heated with a solution of potash or soda, and when the solution is concentrated, it is almost immediately converted into a soap. The soap separates from the liquid when sufficiently concentrated, and swims on the surface as long as the heat continues; on cooling it constitutes a hard mass, like white colophon. This soap is soluble in ether, alcohol, and water, and is decomposed by acids.

Twenty-eight grains of pure lithofellic acid being saponified by soda, and the soap decomposed by muriatic acid, left 24·375 grains of white dry lithofellic acid. The chloride of sodium weighed 4·875 grains. This quantity corresponds with 2·553 of soda. Hence the soap is composed of

Lithofellic acid,	24·375 or	38·19
Soda, . .	2·553 or	4

Lithofellic acid dissolves in liquid ammonia, and is again precipitated unaltered in the state of a white powder by muriatic acid. If we heat the solution on the water-bath decomposition takes place, the lithofellic acid being precipitated in plates. The soda soap of this acid gives heavy and insoluble precipitates with salts of silver, mercury, iron, lead, platinum, lime, and barytes.

By the action of nitric acid on lithofellic acid a new acid is formed, which has a lemon-yellow colour, dissolves in soda ley, and separates as a soap from the concentrated ley. Muriatic acid throws down a brown mass insoluble in water, which on cooling becomes solid.

This acid was subjected to an ultimate analysis by burning it

with oxide of copper by MM. Ettling and Will. 573·5 parts of it gave 1480·5 of carbonic acid, and 558·5 of water. Hence the constituents are

Carbon, . .	70·41
Hydrogen, . .	10·82
Oxygen, . .	18·77
	100*

From an analysis of lithofellate of silver they have been induced to represent its constitution by the formula $C^{42}\ H^{38}\ O^{8} = 44.25$. If we calculate from this formula we get

42 carbon	= 31·5 or per cent	71·19
38 hydrogen	= 4·75 .	10·73
8 oxygen	= 8 .	18·08
	44·25	100·00

Were we to adopt the atomic weight of 38·125 derived from Goebel's analysis of the soda soap, we might consider lithofellic acid as composed of $C^{36}\ H^{33}\ O^{7} = 38{\cdot}125$—a formula which approaches the numbers obtained by the analysis of Ettling and Will pretty nearly. Wöhler gives the formula $C^{40}\ H^{36}\ O^{8} = 42{\cdot}5$, which agrees very closely with his analysis. He obtained

Carbon, .	70·83
Hydrogen, .	10·60
Oxygen, . .	18·57
	100†

The lithofellate of lead was composed of

Acid, . .	68 or 44.6
Oxide of lead, .	32 or 21 or 1½ atom
	100

This would make the atomic weight of the acid 44·6. The silver salt, according to Wöhler's analysis, is composed of

Lithofellic acid, .	75 or 43·5
Oxide of silver, .	25 or 14·5
	100

* Ann. der Pharm. xxxix. 244. † Ibid. xli. 154.

Wöhler considers the formula $C^{40} H^{36} O^{8} = 42{\cdot}5$ as most probable, because the acid has all the characters of a resin.

SECTION XVI.—OF BUTYRIC ACID.

The existence of this acid was announced by Chevreul in 1814; but it was not till the year 1818 that he got it in a state of purity. As the name indicates, it is obtained from butter. It has been described in detail in the Chemistry of Inorganic Bodies, (ii. 132,) and we have no additional information to state. To that work, then, we refer the reader.

The constitution of butyric acid, according to the analysis of Chevreul, is $C^{8} H^{5} O^{3} = 9{\cdot}625$.

SECTION XVII.—OF PHOCENIC ACID.

This acid was extracted from the oil of the porpoise, (*Delphinus globiceps,*) by Chevreul in 1817. There is nothing to add to the account given of it in the *Chemistry of Inorganic Bodies,* (ii. 130.)

According to the analysis of Chevreul, the constitution of this acid is $C^{10} H^{7\frac{1}{2}} O^{3} = 11{\cdot}4375$. It is exceedingly probable from this analysis, that phocenic acid is identical with the sebacic.

SECTION XVIII.—OF CAPROIC ACID.

Discovered by Chevreul in 1818 in the butter of the *cow* and *goat.* It has been described in the Chemistry of Inorganic Bodies, (ii. 134.)

According to Chevreul's analysis, it is composed of $C^{12} H^{10} O^{3} = 13{\cdot}25$.

SECTION XIX.—OF CAPRIC ACID.

Discovered by Chevreul in 1818 in the butter of the cow and goat. It has been described in the Chemistry of Inorganic Bodies, (ii. 136.)

Its constituents are $C^{18} H^{14} O^{3} = 18{\cdot}25$.

SECTION XX.—OF HIRCIC ACID.

The few facts ascertained by Chevreul respecting this acid have been stated in the Chemistry of Inorganic Bodies, (ii. 137.)

It has not hitherto been analyzed.

SECTION XXI.—OF AMBREIC ACID.

Described in the Chemistry of Inorganic Bodies, (ii. 141.)

SECTION XXII.—OF CASTORIC ACID.

This acid was obtained by Brandes* from *castorin*, a substance extracted from *castor*, which is secreted in two bags in the inguinal regions of the beaver.

When castorin is treated with nitric acid till it is completely decomposed, and the residual liquid concentrated, small yellow prisms and grains are deposited, which constitute castoric acid.

It reddens litmus-paper; it is soluble in water, and the solution is yellow; it forms with ammonia a supersalt, which crystallizes in small grains. This salt, when neutral, does not precipitate the salts, having the alkaline earths for bases. But it throws down the salts of protoxide of iron *white*; the salts of copper *light-green*; the salts of lead and the nitrate of silver *white*; and these last precipitates do not alter their colour by exposure to the air.

SECTION XXIII.—OF BOMBYCIC ACID.

It was observed by Chaussier in 1783, that silk-worms have the property of reddening litmus-paper. Hence he inferred that they contained a peculiar acid.† It appears, from Chaussier's statement, that Boissier de Sauvage had already noticed this acid; but neither of them gave any account of its properties, or seem to have attempted to procure it in a separate state.

In 1836, M. Mulder mixed together 100 grammes of raw yellow silk and 50 grammes of sulphuric acid previously diluted with 5 litres of water in a retort, and distilled cautiously that the heat might not be sufficiently high to injure the silk.‡ The liquid which came over was acid, and had a strong and peculiar smell. To free it from any sulphuric acid which it might have contained, an excess of barytes water was added, and the sulphate of barytes being separated, the uncombined barytes which it might still contain was thrown down by a current of carbonic acid gas. The liquid was then evaporated to dryness, and a saline crust was obtained, which was bombycic acid. When a little sulphu-

* Br. Arch. xvi. 281.

† Nouv. Mem. de Dijon. 1783, p. 70; or Crell's Annalen, 1788, i. 576.

‡ Poggendorf's Annalen, xxxvii. 611.

ric acid was mixed with this crust, a sharp and penetrating smell was perceived, and a white vapour exhaled, which acted as an acid. From this experiment it follows, that silk contains an acid which is separated from it by sulphuric acid; that this acid is volatile, has a strong smell, and forms a soluble salt with barytes.

Bombycic acid is not found in the fibres of silk, but in its gelatin and albumen. It may be obtained by boiling the raw silk in water, and evaporating the liquid.

When mixed with a great deal of water, it has a peculiarly strong fatty smell, is very volatile; has a sharp taste, and reacts weakly as an acid. When exposed to the light, it is decomposed; the peculiar smell vanishes, and a crop of mucors make their appearance.

It forms soluble salts with lime, barytes, potash, soda, and ammonia, and is separated from these bases by the strong acids, as becomes evident by the smell. Its solution in water is not precipitated by salts of iron, mercury, copper, and silver, showing that its combinations with the bases of these salts are soluble.

Concentrated acids mixed with dilute aqueous solutions of bombycic acid do not act upon it, if we except muriatic acid, which occasions a smell similar to that of iodine.

It is obvious, from the characters of this acid, thus determined by Mulder, that it is neither *cyanic* acid, as Liebig conjectured, nor *benzoic* acid, as was the opinion of Proust.

CHAPTER II.

ANIMAL ACIDS CONTAINING AZOTE.

These acids are all, or at least the greater number of them, feeble. They amount at present to about eighteen species; but they will probably be greatly augmented as the examination of animal substances proceeds.

SECTION I.—OF CYANOGEN AND ITS COMPOUNDS.

These have been treated of at great length in the *Chemistry of Inorganic Bodies*, (Vol. ii. p. 208,) and in the *Chemistry of Vegetable Bodies*, (p. 207.) But the compounds of this very prolific substance are so numerous, that it may not be improper to give a list of the principal of them in this place.

Cyanogen, $C^2 Az = 3.25$

1. Chloride of cyanogen, $C^2 Az + Chl. = 7.75.$*
2. Bromide of cyanogen, $C^2 Az + Br. = 13.25.$†
3. Iodide of cyanogen, $C^2 Az + Iod. = 19.$‡
4. Sulpho-cyanogen, $C^2 Az + S^2 = 7.75.$

1. Cyanic acid, $C^2 Az O + Aq = 5.375.$§
2. Fulminic acid, $2 (C^2 Az O) = 4.25.$‖
3. Cyanuric acid, $3 (C^2 Az O) + 3 HO = 7.625.$¶

1. Cyanate of ammonia, $C^2 Az O + Az H^3 + HO = 6.5.$
   Urea, $C^2 Az O + Az H^3 + HO = 6.5.$
2. Cyanate of potash, $C^2 Az O + KO = 11.375.$ And so of the other cyanates.

1. Fulminate of mercury, $2 (C^2 Az O) + 2 (Hg O) = 35.5.$
2. Fulminate of silver, $2 (C^2 Az O) + 2 (Ag O) = 37.5.$
3. Fulminate of copper, $2 (C^2 Az O) + 2 (Cu O) = 14.25.$
4. Fulminate of Zinc, $2 (C^2 Az O) + 2 (Zn O = 14.5.$ And so of the other fulminates.

1. Crystallized cyanuric acid, $3 (C^2 Az O) + 3 (HO) + 4 Aq = 15.5.$
2. Cyanurate of ammonia, $3 (C^2 Az O) + Az H^3 + HO = 10.875.$
3. Cyanurate of potash, $3 (C^2 Az O) + 2 (HO) + KO = 15.875.$
   or $3(C^2 Az O) + HO + 2(KO) = 20.75$
   or $3 (C^2 Az O) + 3 (KO) = 35.625.$
4. Cyanurate of silver, $3 (C^2 Az O) + 2 (Ag O) + HO = 37.75.$
   or $3 (C^2 Az O) + 3 (Ag O) = 51.125.$

1. Hydrocyanic acid or prussic acid, $C^2 Az H = 3.375.$**
2. Hydrocyanate of ammonia, $C^2 Az H + Az H^3 = 5.5.$ And so of the other hydrocyanates.

1. Cyanet of potassium, $C^2 Az + K = 8.25.$
2. Cyanet of sodium, $C^2 Az + Na = 6.25$
3. Cyanet of zinc, . $C^2 Az + Zn = 7.375.$
4. Cyanet of iron, . $C^2 Az + Fe = 6.75.$

* See Inorganic Chemistry, ii. 234. † Ibid. ii. 238.
‡ Ibid. ii. 239. § Ibid. ii. 225. ‖ Ibid. ii. 229.
¶ Ibid. ii. 227; and Vegetable Chemistry, p. 208.
** Chemistry of Inorganic Bodies, ii. 219.

5. Cyanet of mercury, C^2 Az + Hg = 15·75.
6. Cyanet of silver, C^2 Az + Ag = 16·75.
7. Cyanet of palladium, C^2 Az + Pa = 10·
8. Cyanet of gold, C^2 Az + 2 (Au) = 28·25. And so of the other cyanets.

1. Ferrocyanogen, 3 (C^2 Az) + Fe = 13·25.
   Symbol for ferrocyanogen Cfy.
2. Ferro-cyanhydric acid Cfy + H^2 = 13.5.
   Ferro-prussic or Ferro-chyazic acid of Porret.
3. Ferrocyanet of potassium, Cfy + 2 K = 23.28.
   Prussiate of potash. But it contains also three atoms water.
4. Ferrocyanet of potassium and iron, 2 Cfy + $\left\{ \begin{matrix} 3\ F \\ K \end{matrix} \right\}$ = 35.
5. Prussian blue, 3 Cfy + Fe^2 = 43.25.
6. Basic prussian blue, 3 Cfy + $\left\{ \begin{matrix} 2\ Fe^2 \\ Fe^2 \end{matrix} \right\}$ + Fe $O^{1\frac{1}{2}}$ = 54·75.
7. Soluble prussian blue, 2 Cfy + $\left\{ \begin{matrix} Fe^2 \\ K \end{matrix} \right\}$ = 38·5.
8. Ferrocyanet of zinc and potassium, 2 Cfy + $\left\{ \begin{matrix} 3\ Zn \\ K \end{matrix} \right\}$ = 41·875
9. Ferrocyanet of ammonium, Cfy + 2 (Az H^4) + 3Aq = 17·625.
10. Ferrocyanet of sodium, Cfy + 2 N + 12 Aq = 32·75. And so of the other ferrocyanets.
11. Ferocyanet of potassium and calcium, Cfy + $\left\{ \begin{matrix} K \\ Cal \end{matrix} \right\}$ = 20·75.
12. Ferrocyanet of potassium and iron, 2 Cfy + $\left\{ \begin{matrix} K \\ 3\ Fe \end{matrix} \right\}$ = 42

This is the greenish white precipitate which falls when a solution of protoxide of iron is mixed with prussiate of potash.

13. Basic cyanodide of iron, 3 Cfy + $\left\{ \begin{matrix} 2\ Fe_2 \\ FO^{1\frac{1}{2}} \end{matrix} \right\}$ = 58·25

The preceding salt washed and then dissolved in water:

1. Ferricyanogen, 2 Cfy = 26·5.
   The supposed basis of Gmelin's red prussiate of potash:
2. Ferricyanhydric acid, 2 Cfy + 3 H = 26·875.
3. Ferricyanet of potassium, 2 Cfy + 3 K = 41·5.
   Gmelin's red prussiate of potash:
4. Ferricyanet of iron, 1 atom ferricyanogen, = 26·5.
   3 atoms iron, = 10·5.
   37·

This is the blue precipitate thrown down from a solution of protoxide of iron by the red prussiate.

1. Sulphocyanogen, C_2 Az + S^2 = 7·75.[*]
2. Sulphocyanhydric acid, (C^2 Az + S^2) + H = 7·875.
3. Sulphocyanet of ammonium, (C^2 Az + S^2) + Az H^4 = 10.
4. Sulphocyanet of potassium, (C^2 Az + S^2) K = 12·75.
5. Sulphocyanet of lead, (C^2 Az + S^2) + Pb = 20·75.
6. Basic sulphocyanet of lead, (C^2 Az + S^2) + Pb + PbO = 34·75.
7. Sulphocyanet of mercury, (C^2 Az + S^2) + Hg = 20·25.

SECTION II.—OF URIC ACID.

This very important substance was discovered, and its characters ascertained by Scheele, in 1776.† He found it in urinary calculi; and all the calculi examined by him consisted of it. From the properties of it pointed out by Scheele, it was considered as an acid, and Morveau gave it the name of *lithic acid.*‡ The experiments of Scheele were confirmed by those of Bergman,§ and of Fourcroy and Vauquelin during their examination of urinary calculi.‖ In 1798, a long paper on urinary calculi by Dr Pearson was inserted in the Philosophical Transactions.¶ It contained little that had not been already determined by Scheele. But Pearson affirmed that the characters of the lithic acid of Scheele were not those of an acid. He called it an *oxide*, and the term *lithic* being in his opinion improper, he distinguished it by the name of *uric oxide;* a term which he had already employed in his translation of the French Chemical Nomenclature.** Fourcroy, admitting the impropriety of the name *lithic*, but still maintaining that the substance was an acid, gave it the name of *uric acid*, which was generally adopted.††

Brugnatelli made some experiments on this acid, one of which

* Inorganic Chemistry, ii. 241.

† Kongl. Vet. Acad. Handbl. 1776, p. 327; or Scheele's Chemical Essays, p. 199.

‡ *Encycl. Meth. Chemie Art. Acides*; or Lavoisier's Traité de Chimie, p. 318.

§ Kong. Vet. Acad. Handl. 1776, p. 333.

‖ Ann. de Chim. xvi. 63, and xxvii. 225.

¶ Phil. Trans. 1798, p. 15.

** See the last table in that work.

†† Ann. de Chim. xxvii. 280.

was rather important. He showed that when it was treated with nitric acid, a considerable quantity of oxalic acid was formed.* This throws some light upon the existence of oxalate of lime in urinary calculi; for Scheele had shown that uric acid is a constant ingredient in urine.

Gay-Lussac first attempted to analyse uric acid by means of black oxide of copper. He measured the volumes of carbonic acid and azotic gases evolved, and found them to each other as 69 : 31, or as 5 : 2·246.† This, as we shall see afterwards, constitutes a tolerably near approximation to the truth. The properties of *uric acid* were farther investigated by Dr Henry, who made it the subject of his thesis, when he took his medical degree at Edinburgh in 1807. His experiments were revised and published in an English dress in 1813.‡ Berard subjected it to analysis, and published the result in his thesis on the analysis of animal substances, which he supported at Montpellier, when he graduated in that University in 1817.§ In the same year an important paper by Dr Prout, *on the nature and proximate principles of urine*, was published in the eighth volume of the *Medico-Chirurgical Transactions*. He gives an analysis of uric acid, remarkable for the care and accuracy with which it was conducted. Uric acid was again analyzed by Kodweiss in 1830,‖ by Mitscherlich,¶ and by Liebig** in 1834.

Scheele had observed that when uric acid is distilled, an acid substance sublimed, which he considered as analogous to *succinic acid*. Dr Pearson obtained it also, and considered it as *benzoic* acid. It was examined more in detail by Dr Henry, who concluded from his experiments that it was a new acid united to ammonia. The subject was taken up by Chevallier and Lassaigne in 1820.†† These gentlemen examined its properties in detail, showed its peculiar characters, subjected it to analysis, and distinguished it by the name of *pyruric acid*.

In the year 1838, a most important set of experiments on uric acid, and the various new compounds which it is capable of yield-

* Ann. de Chim. xxviii. 56.

† Ibid. xcvi. 53.

‡ Memoirs of the Literary and Philosophical Society of Manchester, (2d Series), Vol. ii.

§ Ann. de Chim. et de Phys. v. 292.

‖ Poggendorf's Annalen, xix. 1.

¶ Ibid. xxxiii. 335.

** Annalen der Pharmacie, x. 47.

†† Ann. de Chim. et de Phys. xiii. 158.

ing, was published by Wöhler and Liebig.* These chemists have thrown a new light upon the nature of uric acid, and on the important part which it acts in the animal economy. If the view which they have taken prove correct,—and it agrees better with the phenomena than the old opinion,—the statement of Dr Pearson, that uric acid is not entitled to be considered as a real acid, will after all be the true one. Liebig and Wöhler consider it as a *salt* having *urea* for its base. The other, or *acid* constituent, has never been obtained in a separate state, and perhaps is incapable of existing except when united to a base.

Uric acid exists in small quantity in human urine, and may be obtained in crystals when that liquid is cautiously concentrated. Many urinary calculi consist almost entirely of it. In them, however, it is mixed with the colouring matter of urine, with the mucus of the bladder, and with other substances. The urine of birds, as was first shown by Dr Wollaston, consists chiefly of urate of ammonia. The excrements of serpents (voided about once a month) consist almost entirely of the same substance.

The easiest method of obtaining uric acid is to take the excrements of serpents or of birds, which are solid, nearly white, and consist of urate of ammonia, mixed with more or less of animal matter. Dissolve this matter by means of heat in a ley of caustic potash or soda, and evaporate the solution to a thick magma. Spread this magma upon a fine cloth, and wash it cautiously with hot water till the liquid passes off colourless; then subject it to strong pressure between folds of blotting-paper. Dissolve it in boiling water, and precipitate the uric acid by means of muriatic acid. Collect it on a filter, and wash it with cold water till that liquid ceases to have any taste.

Thus obtained, uric acid has a snow-white colour, and is usually in fine powder, though sometimes in very minute prismatic crystals. It has been obtained in pretty large crystals by Böttger. They were hydrated uric acid composed of one atom uric acid, and four atoms water.†

It is destitute of taste and smell. According to Dr Henry, it dissolves in about 1400 times its weight of boiling water, and the

* Annalen der Pharmacie, xxvi. 241; or Ann. de Chim. et de Phys. lxviii. 225.

† Ann. der Pharm. xxxii. 315.

solution reddens litmus-paper.* Dr Pearson states it to be insoluble in cold water, and with his statement my trials agree. It certainly requires more than 10,000 times its weight of cold water to dissolve it. Muriatic acid does not dissolve it, nor sulphuric acid, but it dissolves with effervescence in nitric acid when assisted by heat, and if the solution be cautiously evaporated to dryness, the residue gradually assumes a beautiful pink colour. Water dissolves this residue, and assumes the same pink colour, but it gradually fades and disappears. The alkaline carbonates do not dissolve uric acid, but it dissolves readily in caustic potash or soda ley, and also in ammonia, though less readily. The alkaline solutions are promoted by heat. It decomposes soap when assisted by heat, as it does also the alkaline sulphurets. Lime-water also dissolves uric acid, as was first shown by Scheele. It is insoluble in alcohol and ether.

M. Lipowitz* has made some experiments on the solubility of uric acid, which deserve to be stated. One part of carbonate or bicarbonate of potash or soda, dissolved in 90 parts water, dissolves two of uric acid. The mixture must be boiled. During the boiling, the carbonic acid is expelled and an alkaline urate formed. On cooling, the urate is deposited in warty crystals, which require much water to dissolve them. The affinity of uric acid for bases is augmented by heat. When uric acid is boiled with a solution of acetate of potash, the acetic acid is disengaged and urate of soda formed. On cooling, the acetic acid again displaces the uric. When one part of borax is dissolved in ninety parts water, the solution dissolves little more than one part of uric acid, but the solution does not require heat. A gelatinous biurate of soda separates. When this salt is burnt, it leaves carbonate of soda. When we add boracic acid so as to form 2 atoms biborate of soda + 1 atom uric acid, and heat, we get 2 atoms urate of soda + 1 atom quaterborate of uric acid. On cooling, we have 1 atom biurate of soda + 1 atom biborate of soda + 1 atom biborate of uric acid.

When phosphate of soda is dissolved in water and the solution boiled with uric acid, urate of soda is formed, which is deposited on cooling, and the liquid becomes acid.

Carbonate of lithia requires 200 times its weight of water to dissolve it. If it be suspended in water, mixed with uric acid,

* Ann. der Pharm. xxxviii. 348.

and heated, a solution immediately takes place: 1 part of lithia, and 1 of uric acid, dissolve in 90 parts water, at the temperature of 122°, and they remain in solution when the liquid is cooled. At the boiling point, 1 part of lithia, and almost 4 parts of uric acid dissolve in 90 parts of water, with the evolution of much carbonic acid. On cooling, the whole concretes into a gelatinous mass, easily redissolved by heat. Urate of lithia at 122° is soluble in sixty times its weight of water. Caustic lithia dissolves about six times its weight of uric acid. Urate of lithia is composed of

Uric acid,	85·54 or	10·35 or	1 atom.
Lithia, .	14·46 or	1·75 or	2 atoms.
	100·00		

M. Lipowitz proposes lithia as an excellent reagent for separating uric acid from the other ingredients in calculi. We have only to heat the powdered calculus with a solution of lithia; filter and add muriatic acid; pure uric acid falls down. He boiled lepidolite in fine powder with uric acid. On dropping muriatic acid into the filtered liquid, uric acid precipitated. The same experiment succeeded with spodumen, containing lithia.

When dry uric acid is heated in chlorine gas, cyanic acid, muriatic acid, and chloride of cyanogen are formed. When moist uric acid is subjected to the same treatment, the substances formed are carbonic acid, ammonia, and oxalic acid. When it is long boiled in caustic potash ley ammonia is given out, and oxalic acid formed.

According to Braconnot it combines with the alkalies in two proportions, forming with each, *urates* and *diurates*. The diurate of potash, according to his analysis is composed of

Uric acid, .	66·4 or	23·1
Potash, .	33·6 or	12·
	100·	

According to this analysis its atomic weight is 23.

When the alkaline urates are heated to redness in the open air, the residue is a mixture of charcoal and carbonate of the alkali. But when the experiment is conducted in close vessels, cyanodide of the alkali, cyanate and carbonate are formed, as appears from the experiments of Lipowitz.*

* Ann. der Pharm. xxxviii. 356.

The following table exhibits the result of the different ultimate analyses of uric acid:

	Berard.	Prout.	Kodweiss.	Mitcherlich.	Liebig.
Carbon, .	33·62	39·875	39·79	35·82	37·15
Hydrogen,	7·06	2·225	2·00	2·38	2·49
Azote, .	39·23	31·125	37·40	34·60	34·66
Oxygen, .	20·09	26·775	20·81	27·20	25·70
	100·00	100·	100·	100·	100·

If we leave out Berard's analysis, because his hydrogen differs so much from all the others, the mean of these analyses gives,

Carbon, .	38·16
Hydrogen, .	2·27
Azote, .	34.45
Oxygen, .	25·12
	100·00

Now the number of atoms which agrees best with this mean, and which approaches the atomic weight determined by Braconnot, is the following:

		per cent.
10 atoms carbon, .	7·5 or per cent.	35·72
4 atoms hydrogen,	0·5 ...	2·38
4 atoms azote, .	7·0 ...	33·33
6 atoms oxygen, .	6·0 ...	28·57
	21·0	100·00

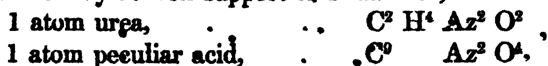
The carbon does not agree with the above mean, but it almost coincides with the result of Mitcherlich's analysis. The quantity of oxygen is above the mean; the number of atoms of oxygen deduced from that mean should only be 5½ instead of 6.

I am disposed, in consequence of these discrepancies, to adopt the analysis of Dr Prout as the most exact. It leads to the following atomic constitution:

		per cent.
11 atoms carbon,	= 8·25 or per cent.	37·94
4 atoms hydrogen,	= 0·5 ...	2·30
4 atoms azote,	= 7·0 ...	32·18
6 atoms oxygen,	= 6·0 ...	27·58
	21·75	100·00

Wöhler and Liebig have adopted the formula, $C^{10} H^4 Az^4 O^6$,

but $C^{11} H^4 Az^4 O^6$ would have answered their purpose as well. They consider uric acid to be a compound of 1 atom urea and 1 atom of a peculiar acid represented by the formula, $C^8 Az^2 O^4$; but we may as well suppose it $C^9 Az^2 O^4$, and then we have

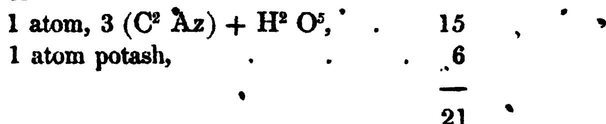


1 atom urea, . . .	$C^2 H^4 Az^2 O^2$
1 atom peculiar acid, . .	$C^9 \quad Az^2 O^4$,

Making 1 atom of uric acid, $C^{11} H^4 Az^4 O^6 = 21{\cdot}75$

When uric acid is subjected to distillation in a retort, it furnishes a considerable quantity of cyanuric acid and urea.

From the late experiments of Liebig, it would appear that the atomic weight of cyanuric acid ought to be doubled. If so, it consists of 3 $(C^2 Az)$ $Az^3 O^6 = 16{\cdot}125$. This being the atomic weight of the acid, it is clear that the salt formerly called bicyanurate of potash is, in fact, a cyanurate, and when heated to 212°, the cyanuric acid loses an atom of water; for the salt is composed of



1 atom, 3 $(C^2 Az) + H^2 O^5$, .	15
1 atom potash, ...	6
	21

He analyzed the salt formerly called cyanurate of potash, (but which will be a dicyanurate if we double the atomic weight of the acid), and found it had lost another atom of water, the acid now consisting of $(C^2 Az)^3 HO^4$.

He analyzed cyanurate of silver, and found it a compound of three atoms oxide of silver, with a new modification of cyanuric acid. For it is deprived of an additional atom of water, and consisted of $(C^2 Az)^3 O^3 = 12{\cdot}75$.*

Thus it appears that cyanuric acid exists in three states.

When uncombined it is .	$(C^2 Az)^3 H^3 O^6 = 16{\cdot}125$
When united to 1 atom potash, . .	$(C^2 Az)^3 H^2 O^5 = 15.$
United to 2 atoms potash, .	$(C^2 Az)^3 H \; O^4 = 13{\cdot}875$
United to 3 atoms oxide of silver,	$(C^2 Az)^3 \quad O^3 = 12{\cdot}75$

An additional atom of base always displacing a corresponding atom of water.

Now, neither urea nor cyanuric acid, in any of these four states, is volatile; yet they are obtained from uric acid by sublimation. But the cyanuric acid may be a product from the de-

* Ann. de Chim. et de Phys. lxviii. 18.

composition of urea, if we admit with Wöhler and Liebig, that urea is one of the constituents of uric acid.

SECTION III.—OF PYRURIC ACID.

It has been stated in the last section, that when Scheele subjected uric acid to distillation, a substance sublimed which he took for succinic acid; that Dr Pearson considered it to be benzoic acid; that Dr Henry examined it more in detail, and was of opinion that it constituted a new and peculiar acid; and, finally, that Chevallier and Lassaigne subjected it to a rigorous examination, and gave it the name of *pyruric acid.*

It may be obtained either by heating uric acid, or uric acid calculi in a retort: the calculi must be pulverized and washed with boiling water before being put into the retort. The acid sublimes in plates, which attach themselves to the upper part of the retort. Besides this there is a good deal of acid, combined with ammonia, dissolved in the water which comes over into the receiver. There comes over at the same time cyanuric acid, and, in general, carbonate of ammonia, and an empyreumatic oil.

The acid may be obtained from the matter which has passed into the receiver, and which speedily assumes a solid form. This matter is to be treated with boiling water, and filtered. The filtered liquor lets fall a brown bituminous-looking substance. When saturated with ammonia and evaporated, small crystals are formed, consisting of super-pyrurate of ammonia, but discoloured by an empyreumatic oil. Being dissolved in water, and the solution mixed with diacetate of lead, a precipitate falls, which, being washed with water, and decomposed by sulphuretted hydrogen gas, filtered and evaporated, yields crystals of pyruric acid. The colour is still yellow, but they may be purified by repeated solutions and crystallizations.

Pyruric acid is white. It crystallizes in small needles. When heated it melts and sublimes entirely in white needles. When passed through a red-hot glass-tube it is decomposed into charcoal, oil, carburetted hydrogen, and carbonate of ammonia. It dissolves in about forty times its weight of cold water. The solution reddens vegetable blues. It dissolves in boiling alcohol (of 0·843) and when the solution cools is deposited in small white grains.

It dissolves in concentrated nitric acid. When the solu-

tion is evaporated to dryness we obtain the pyruric acid unaltered.

Lime forms with pyruric acid a salt which crystallizes irregularly, and which has a bitter and slightly acrid taste. When exposed to a gentle heat this salt melts, and on cooling assumes the appearance of yellow wax. When calcined in a platinum crucible it left 8·6 of lime. Hence Chevallier and Lassaigne concluded that it was a compound of

Pyruric acid,	91·4 or 37·1	
Lime,	8·6 or 3·5	
	100·0	

When barytes is united to this acid a white pulverulent salt is obtained little soluble in cold water. With potash and ammonia it forms soluble and crystallizable salts. The pyrurate of soda is soluble, but it does not crystallize. The acids when dropt into a solution of these salts precipitate the pyruric acid in the form of a white powder. Of all the metallic salts tried, only the salts of peroxide of iron, black oxide of copper, oxide of silver, oxide of mercury, and the trisacetate of lead are precipitated by the pyrurate of potash.

The pyrurate of peroxide of iron has a chamois-leather colour, that of copper is light-blue, and those of silver, mercury, and lead white. The salt of lead formed by mixing solutions of pyrurate of soda and trisacetate of lead is composed, according to Chevallier and Lassaigne, of

Pyruric acid,	28·5 or 16·6
Oxide of lead,	71·5 or 48 or 3 atoms.
	100·0

If we suppose the pyrurate of lime analyzed to be a bisalt and this a tris-salt, the atomic weight of pyruric acid will be 17·5. It was analyzed by Chevallier and Lassaigne, who obtained

Carbon,	28·29
Hydrogen,	10·00
Azote,	16·84
Oxygen,	44·32
	99·45

There is no likelihood that these numbers are exact. The smallest number of atoms that would agree with this analysis is,

4 Atoms carbon,	= 3	or per cent.	27·9
8 atoms hydrogen	= 1	...	9·3
1 atom azote,	= 1·75	...	16·3
5 atoms oxygen.	= 5	...	46·5
	10·75		100

But 10·75 does not at all agree with the atomic weight of pyruric acid, as deduced from the analysis of the two pyrurates above stated, namely, 17·5.*

SECTION IV.—OF PARABANIC ACID.

This acid was discovered by Wöhler and Liebig in 1838.† They prepared it in the following way: Uric acid was dissolved by means of heat in eight times its weight of moderately strong nitric acid, and after all evolution of gas had ceased, the solution was evaporated. At a certain point of concentration, it deposits colourless, lamellar crystals. Sometimes the whole liquid concretes into these crystals, and sometimes they do not appear till after an interval of some time. These crystals constitute the *parabanic* acid of Wöhler and Liebig. They may be purified by a second crystallization.

The crystals are six-sided prisms, colourless and transparent, they have a strong acid taste, similar to that of oxalic acid. But parabanic acid is more soluble in water than oxalic. The crystals do not effloresce though exposed to the heat of 212°. They preserve their shape and transparency, but assume a red colour. When exposed to a stronger heat they melt; one portion is sublimed while another is decomposed with the disengagement of hydrocyanic acid.

When the cold solution of parabanic acid is mixed with nitrate of silver, a white pulverulent precipitate falls, which is very much increased by the cautious addition of ammonia. The last formed portion of this precipitate is gelatinous.

When this acid is decomposed by oxide of copper the volume of azotic gas evolved is to that of the carbonic acid gas as 1 : 3. Hence it follows that the atoms of azote and carbon in the acid are to each other as 1 : 3.

Wöhler and Liebig analysed parabanate of silver in order to ascertain the atomic weight of the acid. This salt is insoluble in hot water; but, like most of the salts of silver, it dissolves in

* Ann. de Chim. et de Phys. xiii. 155. † Ibid. lxviii. 273

liquid ammonia and in nitric acid. 100 parts of the salt prepared without ammonia yielded 70·6 parts of oxide of silver. Hence it was composed of,

Parabanic acid,	29·4 or 12·06	
Oxide of silver,	70·6 or 29	= 2 atoms.
	100·0	

100 parts of the same salt, which had been thrown down by ammonia, contained 70·11 of oxide of silver, and, therefore, was composed of,

Parabanic acid,	29·89 or 12·34	
Oxide of silver,	71·11 or 29	= 2 atoms.
	100·00	

The mean atomic weight of parabanic acid deduced from these two analyses, (supposing the salt to contain two atoms of oxide of silver,) is 12·2.

The crystals of parabanic acid were analyzed three times successively in Liebig's laboratory. The mean result of these analyses give the composition as follows:

Carbon,	31·66
Hydrogen,	1·95
Azote,	24·62
Oxygen,	41·77
	100·00

We have just seen that the atoms of azote are to those of carbon as 1 : 3. But if we were to calculate the number of atoms on the supposition that 24·62 represented only 1 atom of azote, we would obtain 7·125 for the atomic weight. While from the analysis of parabanate of silver we know that the atomic weight is above 12. It is clear from this that the acid must contain 2 atoms of azote. Hence its constitution must be,

Six atoms carbon	= 4·5, or per cent,	31·58
Two atoms hydrogen	= 0·25	1·75
Two atoms azote	= 3·5	24·56
Six atoms oxygen	= 6·0	42·11
	14·25	100·

This would make the atomic weight of parabanic acid 14·25. But the atomic weight deduced from the parabanate of silver is 12·2. The difference amounts to 2·05, or very nearly two atoms

of water. It would appear from this, that when parabanic acid is united with oxide of silver it parts with two atoms of water, which are replaced by two atoms oxide. Hence the acid united with the oxide of silver contains no hydrogen, but is composed of $C^6 Az^2 O^4 = 12$.

No other parabanate but that of silver is known. Whenever the acid is placed in contact with a soluble base it is converted, under the influence of the most gentle heat, into *oxaluric acid.* When heated with other acids it undergoes no alteration. Nor is it altered when its aqueous solution is boiled.

SECTION V.—OF OXALURIC ACID.

This acid also was discovered by Wöhler and Liebig in 1838,* during their important examination of uric acid and its compounds.

Parabanic acid, the preparation of which was given in the preceding section, is very soluble in caustic ammonia, and the solution is perfectly neutral. If it be raised to the boiling point, and then left to itself, it concretes on cooling into a white magma composed of small needles. This substance is *oxalurate of ammonia.* If, to a hot concentrated solution of this salt in water, we add sulphuric or muriatic acid, and cool the mixture as quickly as possible, oxaluric acid falls in a white crystalline powder. It may be purified by washing it in cold water, as it is but little soluble in that liquid.

Its solution has a decidedly acid taste, reddens litmus paper, and neutralizes the bases. The neutral oxalurates, when dissolved in water, precipitate nitrate of silver in white flocks, which dissolve in boiling water, and crystallize on cooling in long silky needles.

Neither oxaluric acid nor oxalurate of ammonia throw down any precipitate when dropped into dilute solutions of salts of lime. But, if we add an excess of ammonia, a white gelatinous precipitate falls, soluble in a great deal of water.

If we boil free oxaluric acid in water till no crystals are deposited on cooling, the acid is completely decomposed. The solution is very acid. When concentrated, it first deposits crystals of oxalate of urea and then pure oxalic acid.

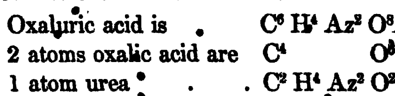
When oxaluric acid is decomposed by oxide of copper, the volumes of azotic gas and carbonic acid gas obtained are to each other as 1 : 3, as is the case with parabanic acid.

* Ann. de Chim. et de Phys. lxviii. 276.

The mean of two analyses in Liebig's laboratory gave the constituents of oxaluric acid as follows:

Carbon,	27·06 or 6 atoms = 4·5	or per cent.	27·27
Hydrogen,	3·07 or 4 atoms = 0·5	.	3·03
Azote,	21·05 or 2 atoms = 3·5	.	21·21
Oxygen,	48·82 or 8 atoms = 8·0	.	48·49
	100·	16·5	100·

Its atomic weight is 16·5. It is easy to see how, by boiling, it is decomposed into urea and oxalic acid.



Oxaluric acid is .	$C^6 H^4 Az^2 O^8$
2 atoms oxalic acid are	C^4 O^6
1 atom urea . . .	$C^2 H^4 Az^2 O^2$



Making together .	$C^6 H^4 Az^4 O^8$

which is obviously an atom of oxaluric acid.

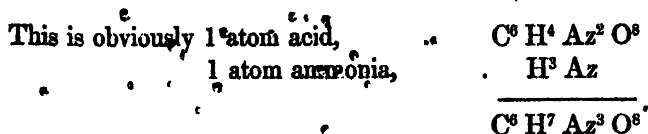
When crystallized oxaluric acid unites to oxide of silver, it parts with an atom of water, which is replaced by an atom of oxide of silver. This is obvious from the composition of oxalurate of silver. The mean of three analyses give

Oxaluric acid, .	51·28 or 15·26
Oxide of silver, .	48·72 or 14·5 = one atom.
	100·

The atomic weight of the acid united to the oxide of silver is 15·26, while that of the crystals is 16·5; the difference, 1·24, is very nearly an atom of water. Hence the acid, when in combination with oxide of silver, is $C^6 H^3 Az^2 O^7 = 15{\cdot}375$. This constitution was confirmed by an analysis of oxalurate of silver by means of oxide of copper.

Oxalurate of ammonia crystallizes in silky needles. It is very soluble in hot, but little soluble in cold water. When heated to 212° it loses no weight. The mean of two analyses by means of oxide of copper gave,

Carbon,	24·07 or 6 atoms = 4·5	or per cent.	24·16
Hydrogen,	4·85 or 7 atoms = 0·875	.	4·70
Azote,	28·08 or 3 atoms = 5·25	.	28·19
Oxygen,	43·00 or 8 atoms = 8·00	.	42·95
		18·625	100·00



This is obviously 1 atom acid, . . $C^6 H^4 Az^2 O^8$
1 atom ammonia, . $H^3 Az$

$C^6 H^7 Az^3 O^8$

When solutions of oxalurate of ammonia and chloride of calcium are mixed, brilliant and transparent crystals of oxalurate of lime are gradually deposited. With excess of lime another precipitate is obtained in a granular and yet gelatinous form. This last compound may be prepared by supersaturating oxaluric acid with lime, or by pouring some ammonia on crystallized oxalurate of lime. It is soluble in a great quantity of water, and very soluble in dilute acids, even in acetic acid.

Oxaluric acid is obviously a combination of two atoms oxalic acid with one of urea.

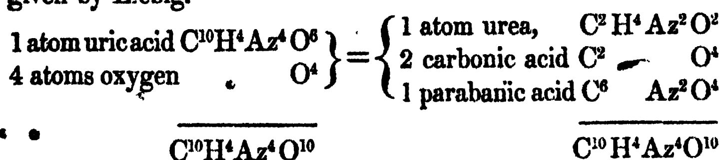


Two atoms oxalic acid, . $C^4 \quad O^6$
One atom urea, . . $C^2 H^4 Az^2 O^2$

Constituting an atom of oxaluric acid, $C^6 H^4 Az^2 O^8$

It deserves attention that the oxalate of urea possesses also acid characters.

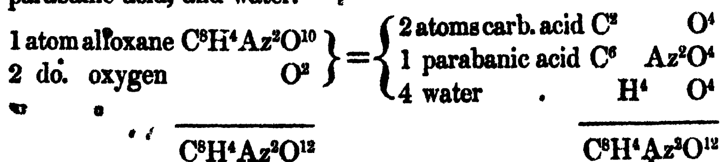
One atom of uric acid + 4 atoms oxygen may be resolved into 1 atom urea, 2 atoms carbonic acid, and 1 atom anhydrous parabanic acid, provided we adopt the constitution of uric acid given by Liebig.



$$\left.\begin{array}{ll}\text{1 atom uric acid} & C^{10}H^4Az^4O^6 \\ \text{4 atoms oxygen} & O^4\end{array}\right\} = \left\{\begin{array}{ll}\text{1 atom urea,} & C^2H^4Az^2O^2 \\ \text{2 carbonic acid} & C^2 \quad O^4 \\ \text{1 parabanic acid} & C^6 \quad Az^2O^4\end{array}\right.$$

$$C^{10}H^4Az^4O^{10} \qquad\qquad C^{10}H^4Az^4O^{10}$$

Alloxane, heated with an excess of nitric acid, combines with two atoms of oxygen, and may be resolved into carbonic acid, parabanic acid, and water.



$$\left.\begin{array}{ll}\text{1 atom alloxane} & C^8H^4Az^2O^{10} \\ \text{2 do. oxygen} & O^2\end{array}\right\} = \left\{\begin{array}{ll}\text{2 atoms carb. acid} & C^2 \quad O^4 \\ \text{1 parabanic acid} & C^6 \quad Az^2O^4 \\ \text{4 water} & H^4 \quad O^4\end{array}\right.$$

$$C^8H^4Az^2O^{12} \qquad\qquad C^8H^4Az^2O^{12}$$

SECTION VI.—OF ALLOXANIC ACID.

This acid was discovered by Wöhler and Liebig in 1838.* They prepared it in the following way:

Barytes water was added to a hot solution of *alloxane.*† A precipitate fell, which was soluble by a gentle heat. On continuing to add barytes water, a point was reached at which the whole liquor became muddy, and being left to itself, a barytes salt was deposited, crystallized in white heavy plates. This salt assumed a red colour when the solution happened to contain a little alloxantin. The liquid which covered these crystals was an aqueous solution of the same salt, and contained nothing else. This salt was *alloxanate of barytes.*

We obtain the same precipitate, though not quite so pure, when we add chloride of barium to a solution of alloxane, and then pour in a little ammonia. The salt in that case is deposited under the form of a thick gelatinous magma, which is completely dissolved by the addition of a great deal of water, or by a dilute acid, however weak.

A similar salt is formed when alloxane is treated in the same way with strontian or lime water, or by chloride of strontium, or of calcium and ammonia. The strontian salt scarcely differs in appearance from that of barytes. The salt of lime presents itself in the form of grains or short transparent prisms. All these salts contain water of crystallization, which they lose when heated to 248°. Alloxane does not precipitate nitrate of silver; but, if we add ammonia to the mixture, a white precipitate falls, which becomes yellow by boiling.

Alloxanate of barytes is easily decomposed by sulphuric acid, and the alloxanic acid obtained from it in a state of purity.

Alloxanic acid possesses considerable power. It decomposes the carbonates and acetates with facility. When evaporated to the consistence of a syrup, it crystallizes in a few days into a hard radiated mass, which does not absorb moisture from the atmosphere. When combined with barytes it forms a salt precisely similar to that from which it was obtained. With ammonia it forms a crystallizable salt. Oxide of silver dissolves in it, and when the solution is dried it resembles gum in appear-

* Ann. de Chim. et de Phys. lxviii. 284.

† This substance, which is obtained by treating uric acid with strong nitric acid, will be described in a subsequent chapter of this volume.

ance. Alloxanate of ammonia precipitates the salts of silver white. The free acid dissolves zinc with the disengagement of hydrogen gas. Sulphuretted hydrogen has no action on it.

Alloxanate of silver was analysed in Liebig's laboratory. It was formed by mixing together solutions of alloxane, ammonia, and nitrate of silver. It became gray when dried, and was found composed of,

Alloxanic acid,	38·53 or 18·17	
Oxide of silver,	61·47 or 29	= 2 atoms.
	100·	

The atomic weight by this analysis is 18·17.

When the salt was decomposed by oxide of copper, the azotic gas and carbonic acid gas evolved were to each other as 1 : 4. The mean of two analyses in Liebig's laboratory gave,

Carbon,	12·91 or 8 atoms	= 6·0 or per cent.	12·84
Hydrogen,	0·68 or 2 atoms	= 0·25	0.54
Azote,	7·53 or 2 atoms	= 3·5	7·48
Oxygen,	17·41 or 8 atoms	= 8·0	17·11
Oxide of silver,	61·47 or 2 atoms	= 29.0	62.03
	100·00	46·75	100.00

This makes the constitution of the acid $C^8 H^2 Az^2 O^8 = 17·75$. Doubtless the crystallized acid contained two atoms of water, which were replaced in the salt by two atoms of oxide of silver. Hence the constituents of the crystals must have been $C^8 H^4 Az^2 O^{10} = 20$.

Alloxanate of silver deflagrates at a temperature much below redness. The residue gives out a considerable quantity of cyanic acid.

Alloxanate of Barytes.—This salt, prepared in the way described in the beginning of this section, constitutes short transparent prisms or a precipitate in brilliant crystalline plates. It loses water when heated to 212°. The crystals then become opaque and milky-white. When decomposed by oxide of copper the volumes of azotic and carbonic acid gases evolved are to each other as 1 : 3. When heated to 248° it loses 20 per cent of water.

100 parts of the salt were found to contain 49·35 of barytes. This was the mean of two analyses, the first yielding 49·25, the second, 49·46 per cent.

When decomposed by oxide of copper, the volume of azotic gas was to that of carbonic acid gas as 1 : 3.

The mean of two analyses, the first by oxide of copper, the second by chromate of lead, gave the following constituents of the salt:

Carbon,	14·20 or 8 atoms	= 6	or per cent.	15.84
Hydrogen,	1·17 or 3 atoms	= 0·375	.	0.99
Azote,	9·21 or 2 atoms	= 3·5	.	9·24
Oxygen,	26·07 or 9 atoms	= 9·0	.	23·76
Barytes,	49·35 or 2 atoms	= 19.0	.	50·17
		37·875		100.

According to this analysis the atomic weight of alloxanic acid is 18·875. But it was afterwards found, that when the salt was heated to 302° it lost 2 per cent of water, which is nearly equivalent to one atom. Hence the atomic weight of the acid is 17·75, and its constitution $C^8 H^2 Az^2 O^8$, and alloxanate of barytes is,

1 atom alloxanic acid, .	17·75
2 atoms barytes, .	19·
	36·75

Alloxanate of Strontian.—This salt may be prepared in the same way as alloxanate of barytes. It is in the form of small acicular transparent crystals, containing water of crystallization. When decomposed, the volumes of azotic and carbonic acid gases obtained are to each other as 1 : 3. At 248° it loses 22·5 per cent of water. 100 parts of the crystals left when ignited, 45·16 of carbonate of strontian, equivalent to 31·73 of strontian. Hence the constituents of the salt are,

Alloxanic acid,	45·77 or 1 atom	= 17·75	or per cent.	44·66
Strontian, .	31·73 or 2 atoms	= 13.00	.	32·70
Water, .	22·50 or 8 atoms	= 9·00	.	22·64
		39·75		100.

Alloxanate of Lime.—When we add chloride of calcium to a solution of alloxane, no precipitate falls until ammonia be added, which occasions the separation of a thick gelatinous deposite, very soluble in acetic acid, and becoming crystalline when

left to itself. It was analyzed by Wöhler and Liebig, and found composed of,

1 atom alloxanic acid, ($C^8 H^2 Az^2 O^8$)	17·75
2 atoms lime,	7·00
2 atoms water,	2·25
	27.

Now alloxane is $C^8 H^2 Az^2 O^8 + 2 (HO)$. Hence it would appear, that when alloxane combines with a base, it divides itself into one atom of alloxanic acid, and 2 atoms of water.

SECTION VII.—OF MYCOMELIC ACID.

When a gentle heat is applied to a mixture of ammonia and alloxane, it becomes yellow, and when cooled and concentrated it concretes into a yellow jelly. This jelly is a combination of ammonia and a new acid, which Wöhler and Liebig, who discovered it, have distinguished by the name of *mycomelic acid.**

If we employ concentrated solutions of alloxane and ammonia, there generally separates, as soon as we apply heat, a heavy yellow powder, which is the same combination. When the liquid assumes a red colour alloxantin is present.

Mycomelate of ammonia dissolved in hot water and treated with an excess of dilute sulphuric acid, gives a transparent gelatinous precipitate of *mycomelic acid,* which when washed and dried assumes the form of a yellow porous powder. We obtain the same acid directly if we supersaturate a hot mixture of alloxane and ammonia with dilute sulphuric acid, and boil the mixture for a few minutes.

Mycomelic acid is very little soluble in cold water, but rather more soluble in hot water. It reddens vegetable blues and dissolves in ammonia and the fixed alkalies, but does not form with them crystallizable salts. Mycomelate of silver is yellow and flocky. It may be obtained by mixing together solutions of mycomelate of ammonia and nitrate of silver. The mixture may be boiled without in the least altering the nature of the salt.

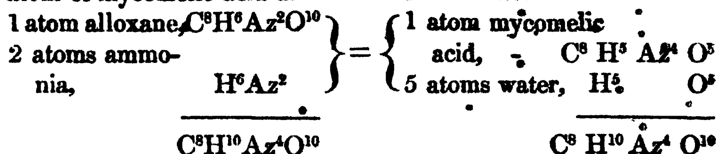
Mycomelic acid, after being dried in the temperature of 248°, was decomposed by means of oxide of copper. The volume of azotic gas evolved was to that of the carbonic acid gas as 1 : 2. The constituents of the acid were found to be,

* Ann. de Chim. et de Phys. lxviii. 295.

Carbon,	31·06	or 8 atoms = 6	or per cent.	32·21
Hydrogen,	3.57	or 5 atoms = 0·625		3·35
Azote,	36·24	or 4 atoms = 7·0		37.59
Oxygen,	29·13	or 5 atoms = 5·0		26·85
	100·00	18·625		100·

The difference between the experimental and calculated results in this case are rather too great. This difference Wöhler and Liebig ascribe to the presence of a little *uramile** in the salt, which is a product of the decomposition of alloxantin by ammonia.

It is easy to explain the formation of mycomelic acid. One atom of alloxane and two of ammonia are decomposed into one atom of mycomelic acid and five atoms of water.



1 atom alloxane, $C^8H^6Az^2O^{10}$; 2 atoms ammonia, H^6Az^2 = 1 atom mycomelic acid, $C^8 H^5 Az^4 O^5$; 5 atoms water, $H^5 O^5$

$C^8H^{10}Az^4O^{10}$ — $C^8 H^{10} Az^4 O^{10}$

Dry mycomelic acid possesses exactly the same composition as allantoin when united to oxide of silver.

Wöhler and Liebig attempted to determine the atomic weight of this acid by analyzing mycomelate of silver, but they did not consider the results which they obtained as deserving of confidence; because the yellow gelatinous precipitate obtained by mixing nitrate of silver with mycomelate of ammonia changes its colour even when washed in the dark. It becomes brown, and when dried on the water-bath assumes the form of a hard green mass, giving an olive coloured powder, not completely soluble in ammonia. They obtained from this salt by combustion 44.39 per cent of silver, equivalent to 47·68 of oxide of silver. This would make the salt,

Mycomelic acid,	52·32	or 15·91	
Oxide of silver,	47·68	or 14·5	= 1 atom.
	100·		

According to this analysis the atomic weight of mycomelic acid is 15·91. The difference between this weight and that of the hydrous acid is 2·715, which is more than two atoms of water.

* This substance will be described in a subsequent chapter of this work.

Were we to admit in the hydrous acid two atoms of water, its constitution would be $C^8 H^3 Az^2 O^3 + 2(HO)$, and its atomic weight in the anhydrous state would be 16·375. But analogy would lead to the inference that the hydrous acid contains only one atom of water, and that its atomic weight is 17·5.

When mycomelate of silver is heated by itself, it gives out a great deal of cyanate of ammonia, which, when dissolved in water and evaporated, becomes urea. There is formed besides a crystalline substance, having a peculiar smell, and coloured red by another matter.

SECTION VIII.—OF DIALURIC ACID.

We owe the discovery of this acid also to Wöhler and Liebig *

When a current of sulphuretted hydrogen gas is passed through a solution of alloxane, this last substance is converted into alloxantin. If we continue the current of sulphuretted hydrogen through the boiling solution after all the alloxane is converted into alloxantin, there is a new deposit of sulphur, and the liquid becomes decidedly acid. If, after all the alloxantin is decomposed, we saturate the liquor with carbonate of ammonia, a great quantity of white crystalline matter falls, consisting of *dialuric acid* united to ammonia.

We may obtain the same salt in abundance by dissolving uric acid in dilute nitric acid, and mixing the liquid with sulphohydrate of ammonia, taking care that there is left in the liquid a slightly acid reaction. The precipitate (which contains sulphur) is to be washed, dissolved in boiling water, and treated with carbonate of ammonia. On cooling the liquid concretes into a white crystalline mass.

If we reduce alloxane by means of zinc and muriatic acid, and after separating the crystals formed, we treat the residue with carbonate of ammonia till the oxide of zinc, at first precipitated, is again redissolved; the same salt is deposited, provided the mixture be left for some time in a state of repose.

This white precipitate becomes red when dried at the common temperature. At 212° it becomes blood red without losing ammonia. It is very soluble in boiling water, but is mostly deposited again when the solution cools, especially if we add carbonate of ammonia to the liquid.

* Ann. de Chim. et de Phys. lxviii. 263.

Its solution precipitates salts of barytes, white; salts of lead in yellow flocks. The precipitate becomes violet when exposed to the air. The salts of silver are immediately reduced by it.

When decomposed by oxide of copper the volume of azotic gas evolved is to that of the carbonic acid gas as 3 : 8. The mean of three analyses made in Liebig's laboratory by means of oxide of copper gave

Carbon,	31·27 or 8 atoms	= 6	or per cent	29·82
Hydrogen,	4·49 or 7 atoms	= 0·875	...	4·34
Azote,	27·36 or 3 atoms	= 5·25	...	26·09*
Oxygen,	36·88 or 8 atoms	= 8·00	...	39·75
	100	20·125		100*

If from $C^8 H^7 Az^3 O^8$ we subtract $H^3 Az$, or an atom of ammonia, the remainder $C^8 H^4 Az^2 O^8$ must give us the constitution of dialuric acid. Its atomic weight is 18. We may consider it as alloxane minus 2 atoms of oxygen, or alloxantin minus 1 atom oxygen and 1 atom water.

Dialurate of ammonia dissolves in potash with the disengagement of ammonia. The acids throw down nothing from the solution.

The attempts of Wöhler and Liebig to obtain dialuric acid in an isolated state were unsuccessful. When separated from its base it is decomposed with great facility into a great number of products which have not yet been accurately examined.

* There is obviously a mistake in the numbers given in Liebig's paper, (Annalen der Pharmacie, xxvi. 277.) The data given,

1st. 0·5095 grammes of dialurate of ammonia gave 0·215 water, and 0·542 carbonic acid.

2d. 0·430 of the salt gave 0·163 water and 0·5635 carbonic acid.

3d. 0 377 gave 0· 455 water and 0·404 carbonic acid.

0·455 water in the third experiment is probably a typographical error for 0·155. But 0·5095 of the salt furnished less carbonic acid than 0·430. This must be a mistake, which affects the quantity of carbon, which of course acts upon the azote and the oxygen. Liebig's numbers are

Carbon,	29·830
Hydrogen,	4·406
Azote,	25·913
Oxygen,	39·851
	100

Numbers coming very near those deduced from the formula $C^8 H^7 Az^3 O^8$.

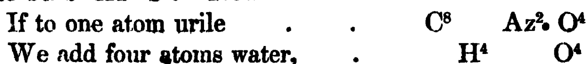
When dialurate of ammonia is moistened with dilute sulphuric acid, that acid combines with the ammonia, and a matter scarcely crystalline remains, which, when dissolved in water, disappears altogether before it can be freed from sulphuric acid. The water employed in washing it deposits, after an interval of some hours, transparent and brilliant crystals of alloxantin. The liquor freed from sulphuric acid by carbonate of barytes, and concentrated, gives a mother liquor, which, being mixed with nitric acid and set aside for some hours, does not deposit nitrate of urea; but it concretes into transparent prisms similar to oxalic acid.

Dialurate of ammonia dissolved in hot muriatic acid gives on cooling a number of crystals similar to those of alloxantin, but differing decidedly in their shape. The muriatic acid solution contains urea.

After having saturated a boiling solution of alloxane with sulphuretted hydrogen, and after ascertaining that the whole alloxane had been converted into the new product, the liquid was concentrated in a retort out of the contact of air. On cooling there was deposited a thick white opaque crust, having brilliant facets. This crust became red when dried. It was very soluble in cold water, had an acid reaction and taste, reduced oxide of silver, gave with barytes a violet-coloured precipitate, and with carbonate of ammonia, a little ammoniacal salt after an interval of some time.

When it is dissolved in boiling water or muriatic acid, the solution, on cooling, deposits transparent crystals similar to alloxantin. The mother liquor scarcely, if at all, reduces the salts of silver. On the addition of ammonia and nitrate of silver, it gives a white precipitate which, by the action of heat, becomes dark-purple, without being reduced. This mother water gives a white precipitate with barytes water.

Wöhler and Liebig distinguish, by the name of *urile*, the hypothetical substance which they suppose to constitute uric acid, when combined with urea: And it has been stated in a preceding section of this chapter, that they consider the constitution of urile to be $C^8\ Az^2\ O^4$. Now



If to one atom urile . . $C^8\ Az^2\ O^4$
We add four atoms water, . $H^4\ O^4$

We obtain an atom of dialuric acid, $C^8\ H^4\ Az^2\ O^8$

SECTION IX.—OF THIONURIC ACID.

This remarkable acid was discovered by Wöhler and Liebig during their researches on uric acid in 1838.*

If we add sulphurous acid to a cold saturated solution of alloxane, it loses its smell. When to such a solution, containing a slight excess of sulphurous acid, we add as much ammonia as will saturate the acid, heat the mixture, and keep it boiling for a short time, it deposites on cooling a considerable quantity of brilliant quadrangular plates. The best method of preparing this substance on a large scale, is to take sulphate of ammonia previously mixed with an excess of carbonate of ammonia, to add to it a solution of alloxane, to raise the mixture to the boiling point, and keep it boiling for half an hour. The salt thus obtained is a combination of *thionuric* acid and ammonia. When dry, it is in thin plates having a strong pearly lustre, soluble in water and again crystallizable without any other alteration than the assumption of a red colour. At 212°, its loses its water and becomes rose red.

Dr Gregory of Aberdeen has given the following process as the easiest for preparing thionurate of ammonia. Take a pretty strong cold solution of alloxan, add to it half its volume of a strong solution of sulphite of ammonia, with a little free ammonia, boil for five minutes. On cooling, a large quantity of thionurate of ammonia is deposited in beautiful silvery scales. They are to be slightly washed and dried by pressure.

If we raise the aqueous solution of this salt to the boiling temperature, and pour into it a solution of acetate of lead, a gelatinous precipitate falls, which, on cooling, assumes the form of fine needles, arranged concentrically, and having sometimes a white, sometimes a red colour. This is *thionurate of lead*. By mixing it with water and passing a current of sulphuretted hydrogen gas through the mixture, the lead is separated, while the acid dissolves in the water. On evaporating the aqueous solution in a gentle heat, the acid is deposited white and crystalline, though the shape of the crystals cannot be determined.

Thionuric acid does not absorb moisture from the atmosphere. It has a decidedly sour taste, and reddens vegetable blues. When we boil its aqueous solution, the acid is decomposed, being

* Ann. de Chim. et de Phys. lxviii. 253.

converted into sulphuric acid and *uramile*.* It becomes muddy during the boiling, and concretes into a silky mass of uramile, while the sulphuric acid remains dissolved in the water.

Though thionuric acid contains sulphuric acid, yet the ordinary reagents are incapable of detecting that acid in thionurate of ammonia. The salts of barytes throw down a thick, flocky, gelatinous precipitate, which is soluble in muriatic acid. The salts of lead behave in the same manner.

A solution of thionurate of ammonia mixed cold with muriatic, sulphuric, or nitric acids, undergoes no alteration at the common temperature, but when boiled for a few minutes, it becomes muddy, and concretes into a white magma, consisting of microscopic needles, having a satiny lustre. This precipitate contains no sulphuric acid; but consists of uramile. After this decomposition, the sulphuric acid may be discovered in the liquor by the usual reagents.

The thionurate of lead being analyzed in Liebig's laboratory, was found to be composed as follows;

Carbon,	10·83 or 8 atoms	= 6	or per cent.	10·7
Hydrogen,	1·04 or 5 atoms	= 0·625	...	1·1
Azote,	9·47 or 3 atoms	= 5·25	...	9·3
Oxygen,	10·83 or 6 atoms	= 6·00	...	10·7
Sulphuric acid,	18·05 or 2 atoms	= 10·00	...	17.9
Oxide of lead,	49·78 or 2 atoms	= 28·00	...	50·3
		55·875		100·0

If we admit, with Wöhler and Liebig, that the salt is a dithionurate, it is obvious that the constitution of thionuric acid is $C^8 H^5 Az^3 O^6 + 2 (S O^3) = 29{\cdot}875$. This conclusion was confirmed by a careful analysis of thionurate of ammonia. Between the tube filled with chloride of calcium, and that containing the caustic potash, a tube was interposed filled with peroxide of lead. This peroxide absorbed the sulphurous acid given out, and converted it into sulphate of lead. The mean of three analyses gave the constituents of the salt as follows:

* This product of uric acid will be described in a subsequent chapter.

Carbon, .	17·84 or	8 atoms =	6	or per cent.	17·45
Hydrogen, .	4·90 or	13 atoms =	1·625	...	4·72
Azote, .	26·01 or	5 atoms =	8·750	...	25·45
Oxygen, .	22·78 or	8 atoms =	8·000	...	23·28
Sulphuric acid,	28·47 or	2 atoms =	10·000	...	29·10
	100		34·375		100

If from the preceding constituents, $C^8 H^{13} Az^5 O^8 + 2 (S O^3)$
We subtract 1 atom thionuric acid, $C^8 H^5 Az^3 O^6 + 2 (S O^3)$

There will remain, . . $H^8 Az^2 O^2$
From this remainder subtract 2 atoms
water, . . . $H^2 O^2$

There will remain, . . $H^6 Az^2$ which is equal to 2 atoms ammonia.

So that thionurate of ammonia consists of

1 atom thionuric acid, $C^8 H^5 Az^3 O^6 \quad 2 (S O^3)$
2 atoms ammonia, . $H^6 Az^2$
2 atoms water, . $H^2 \quad O^2$



$C^8 H^{13} Az^5 O^8 + 2 (S O^3)$

We see that hydrated thionuric acid contains two atoms water, or it is $C^8 H^7 Az^3 O^8 + 2 (S O^3) = 32·125$.

Thionurate of lime is obtained by mixing together hot solutions of thionurate of ammonia and nitrate of lime. It separates under the form of small short prisms, having a satiny lustre. It is composed of

1 atom thionuric acid, .	29·875
2 atoms lime, . .	7·000
	36·875

Thionurate of zinc constitutes small aggregated crystals, which have a lemon-yellow colour. It is very soluble in water, and is obtained by mixing a salt of zinc with a solution of thionurate of ammonia.

A hot solution of thionurate of ammonia mixed with sulphate of copper gives a brown precipitate, approaching to yellow, which is obviously protoxide of copper. By the action of heat, it dissolves completely into a yellowish-brown liquid, and separates again on cooling in an amorphous state.

When thionurate of ammonia is mixed with nitrate of silver, the oxide is reduced to the metallic state, and the silver is deposited on the inside of the tube, giving it the appearance of a mirror.

Thionurate of barytes, recently precipitated, even from a dilute solution, has the form of a gelatinous mass, which gradually becomes opaque and crystalline. When boiled with nitric acid, this salt gives sulphate of barytes, and no sulphuric acid remains free. This shows that the salt is a compound of one atom thionuric acid and two atoms barytes.

The formation of thionuric acid from alloxane and sulphurous acid is easily explained.

1 atom alloxane is . .	$C^8\ H^4\ Az^2\ O^{10}$
1 atom ammonia, . .	$H^3\ Az$
2 atoms sulphurous acid, .	$O^4\ S^2$
Making altogether, .	$C^8\ H^7\ Az^3\ O^{14}\ S^2$
1 atom thionuric acid, .	$C^8\ H^5\ Az^3\ O^{12}\ S^2$
2 atoms water, . .	$H^2\ O^2$
Making together, . .	$C^8\ H^7\ Az^3\ O^{14}\ S^2$

From this we see, that two atoms sulphurous acid and one atom of ammonia unite with one atom of allophane, and the product is one atom of thionuric acid and two atoms of water.

Wöhler and Liebig seem to be of opinion that the sulphurous acid in thionuric acid is converted into sulphuric acid. But there seems no evidence for this. We see only that the elements of two atoms sulphurous acid and one atom ammonia unite with an atom of alloxane, and form thionuric acid. If it existed in the state of sulphuric acid, barytes surely would be able to detect its presence. But we have seen that this is not the case.

SECTION X.—OF URAMILIC ACID.

This acid also was discovered by Wöhler and Liebig during their important investigation of uric acid and its products in 1838.*

It may be obtained by mixing a cold solution of thionurate of ammonia with a small quantity of sulphuric acid, and evaporating the mixture in a gentle heat. The *uramile* separates by little

* Ann. de Chim. et de Phys. lxviii. 308.

and little, and is then decomposed by the free acid. The solution, when concentrated, becomes yellow, and in twenty-four hours crystals of uramilic acid are deposited. The success of this process depends upon the quantity of acid added to the thionurate of ammonia. With too little sulphuric acid, we obtain by evaporation a pap of small flocky crystals, which are white, very confused, and consist of bithionurate of ammonia. It is always more advantageous to prepare this salt first. For we obtain a considerable quantity of uramilic acid by dissolving it anew in sulphuric acid and evaporating.

If we employ too much sulphuric acid, we do not obtain a trace of uramilic acid, but when the liquid is left long exposed to the air, transparent crystals are deposited, which have the form and the characters of dimorphous alloxantin. These crystals are oblique four-sided prisms, belonging probably to the trimetric systems. They are formed of the four faces distinguished by M. G. Rose by the letter *g*, and terminated by a perpendicular plane. This base is so large in proportion to the faces *g*, that the crystals have the form of tables. The obtuse angle of the base is about 121°. Alloxantin, from the dialurate of ammonia, has the same crystalline form. The crystalline shape of alloxantin is also an oblique four-sided prism belonging to the same system; but the obtuse angle of the base is only 105°.

When uramilic acid is deposited slowly from a moderately concentrated solution, it forms pretty large four-sided prisms, which are colourless and transparent, and have a vitreous lustre. From a hot saturated solution, it crystallizes in fine silky needles. When dried by means of heat, it assumes a rose-red colour, without losing any sensible weight. Its solution in water has a feebly acid reaction. It combines with ammonia and the fixed alkalies, and forms with them crystallizable salts. The salts of lime and barytes are not decomposed by free uramilic acid, but the addition of ammonia determines the precipitation of thick white matter, which is again dissolved by the addition of a great quantity of water. Uramilic acid does not throw down nitrate of silver, but if we previously combine the acid with ammonia, we obtain a thick white bulky precipitate.

Uramilic acid dissolves in concentrated sulphuric acid without the evolution of any gas or any change of colour. When long boiled with dilute sulphuric or muriatic acid it undergoes an al-

teration. The liquid, after a certain time, acquires the property of precipitating barytes water violet, whereas at first it gives with it a white precipitate. The acid liquor gives crystals of dimorphous alloxantin.

The reaction of uramilic and nitric acid is remarkable. It dissolves in that acid at first without the evolution of any gas; but if we boil it with concentrated nitric acid, nitrous acid is disengaged. The liquid becomes yellow when concentrated, and gives a notable quantity of white crystalline plates, which are soluble in hot water and crystallize on cooling. With this they form a yellow solution and acetic acid throws down a white powder. This new substance has not been sufficiently examined. It resembles *xanthic oxide.*

When uramilic acid is heated with oxide of copper it furnishes azotic and carbonic acid in volumes, which are to each other as 1 to 3·2. The acid being subjected to an analysis in Liebig's laboratory, the constituents obtained were the following:—

Carbon,	31·64	or 16 atoms =	12	or per cent. 32·43
Hydrogen,	3·63	or 10 atoms =	1·25	... 3·37
Azote,	23·07	or 5 atoms =	8·75	... 23·65
Oxygen,	41·66	or 15 atoms =	15·00	... 40·55
	100·00		37	100·00

These atomic numbers were pitched upon by Wöhler and Liebig from a supposed relation between *uramile* and *uramilic acid.* Uramile is $C^8 H^5 Az^3 O^6$. Now from

2 atoms uramile, ...	$C^{16} H^{10} Az^6 O^{12}$
Subtract 1 atom ammonia, . .	$H^3 Az$
We have	$C^{16} H^7 Az^5 O^{12}$
Add 3 atoms water, . .	$H^3 \quad O^3$
And we get	$C^{16} H^{10} Az^5 O^{15}$

which is an atom of uramilic acid.

Liebig attempted to determine the true atomic weight of uramilic acid by analysing uramilate of silver. But in drying the salt it was accidentally exposed to too high a temperature, and became black. This made the proportion of silver in the salt greater than it ought to have been. It was composed of

Uramilic acid, . .	23·08
Oxide of silver, . .	76·92
	100·

If we admit that in uramilic acid the three atoms water substituted for ammonia and the two atoms of water in the two atoms of uramile are replaced by 5 atoms of oxide of silver, the constitution of the salt would be,

Acid, . . .	31·375	or per cent.	30·29
Oxide of silver, .	72·5		69·71
			100·

Now this does not deviate very far from the result of the analysis of uramilate of silver.

SECTION XI.—OF HIPPURIC ACID.

This acid has been described in the *Chemistry of Vegetable Bodies*, (p. 46.) No additional facts respecting this acid, so far as I know, have been discovered since the publication of that volume, except the formation of hippuric ether, an account of which will be given in the appendix.

Its constitution is $C^{18}\ H^{8}\ AzO^{5} = 21{\cdot}25$.

SECTION XII.—OF CHOLEIC ACID.

This acid constitutes the greatest part of ox bile. It had been considered as an acid by the older chemists and physiologists. Berzelius gave it the name of biliary matter, and Thenard that of *picromel*. But from the recent analysis of ox bile by M. Demarçay* it appears that the old opinion advanced by Cadet, that bile is of a soapy nature, is after all, the true one. Demarçay has shown that the essential constituents of bile are soda, and an oily acid to which he has given the name of *choleic*.† This acid may be obtained pure from ox bile by the following process:—

Evaporate the bile to dryness over the steam-bath and digest the dry residue in alcohol. The choleate of soda will be dissolved, while the *mucus* mixed with the bile is left behind. Distil off the alcohol by a steam heat, and dissolve the residue in water. To

* Ann. de Chim. et de Phys. lxvii. 177.

† From χολη, bile.

this solution add as much sulphuric acid as will exactly neutralize all the soda in the solution, digest for two days in a moderate heat, agitating frequently. Then evaporate to dryness over the water-bath, and digest the residue in alcohol. The choleic acid is dissolved while sulphate of soda in crystals remains behind. Finally, distil off the alcohol, substituting water, and evaporating to dryness over the steam-bath.

Choleic acid thus obtained possesses the following properties: It is a yellow, spongy, pulverulent matter, which rapidly absorbs moisture from the atmosphere. Its taste is very bitter, with an impression of sweetness. Its powder irritates the nostrils and throat. It is insoluble in ether; but very soluble in alcohol, and pretty soluble in water.

It cannot be distilled without decomposition. When heated it melts, swells up and burns with flame, giving out smoke and leaving a bulky charcoal, which may be burned completely without leaving any residue. It melts imperfectly at 248°, and is not decomposed till heated considerably above 400°.

Its solutions redden litmus-paper, and decompose the alkaline and earthy carbonates with effervescence. But in this way we can form only bicholeates. The choleic acid thus combined with a base is precipitated by acetic acid; though that acid does not act on bile. The acids throw down choleic acid in flocks, which soon collect into a brown viscid fluid. Muriatic, sulphuric, and phosphoric acids decompose it into *choloidic* acid and *taurin*.* Nitric acid decomposes it, deutoxide of azote is evolved, and a peculiar white substance formed. The caustic fixed alkalies decompose it into *cholic acid* and ammonia.

M. Demarçay analyzed it by oxide of copper and obtained,

Carbon,	62·82
Hydrogen,	8.91
Azote,	3.30
Oxygen,	24·97
	100·

He analyzed choleate of soda, and obtained for the atomic weight of choleic acid 50·213. The number of atoms which agree best with the atomic weight and analysis are,

* The choloidic acid was described in the last chapter. Taurin is a crystalline substance obtained from bile, which will be described in a subsequent chapter.

41 atoms carbon,	= 30·75	or per cent.	63·23
33 atoms hydrogen,	= 4·125	...	8·48
1 atom azote, -	= 1·75	...	3.60
12 atoms oxygen,	= 12·00	...	24·69
	48·625		100·

If we suppose the acid in the choleate of soda analyzed to retain 2 atoms of water, the atomic weight will be 50.875, which approaches the result of the analysis of Demarçay, 1½ atom water would make the atomic weight 50·3125, which agrees very nearly with the actual analysis of choleate of soda.

A few only of the salts of choleic acid have hitherto been examined. The following are the facts which have been ascertained.

1. *Choleate of Soda.*—To form this salt, (which constitutes bile,) alcoholic solutions of choleic acid and of soda were mixed together till the reaction became alkaline. Then a current of carbonic acid gas was passed through the solution for several hours. Being left at rest, the carbonate of soda separated in small crystals. The liquid was filtered and evaporated to dryness. The residue readily dissolved in alcohol of 0·800 without leaving any residue. Hence it was pure.

The reaction of this salt is weakly alkaline. It has the taste and properties of bile. When evaporated it leaves a brown resinous magma, similar in appearance to choleic acid. When dry it forms a yellow, very light, friable mass, which attracts humidity from the atmosphere. It is soluble in all proportions in water and alcohol. It melts at the same temperature as choleic acid, and concretes into a brown and very friable mass. When heated it behaves like bile.

Bicholeate of Soda may be obtained by digesting choleic acid over bicarbonate of soda.

2. *Choleate of Potash* may be formed in the same way as cholate of soda, and possesses the same properties.

3. *Choleates of Barytes and Strontian* are soluble in alcohol and water. When evaporated they leave a resinous residue like all the choleates.

4. With oxide of lead choleic acid combines in two proportions. When a solution of nitrate of lead is dropt into choleate of soda a neutral choleate is formed. When diacetate of lead is em-

ployed a dicholeate of lead falls. Both are nearly insoluble in water, but soluble in acetic acid. They have a resinous consistence.

5. Nitrate of silver forms with choleate of soda a white precipitate, which by washing is converted into dicholeate of silver. After being dried in vacuo over sulphuric acid, its constituents were,

Cholcic acid,	-	50·58
Oxide of silver,		29·

Now 29 is the weight of two atoms of oxide of silver. Hence the salt is a dicholeate.

SECTION XIII.—OF CHOLESTERIC ACID.

Cholesterin, a substance having some resemblance to spermaceti, and a very frequent ingredient in gall-stones, seems to have been first particularly noticed by Gren in 1788.* In the year 1817, the action of nitric acid upon this substance was particularly examined by Pelletier and Caventou.† They ascertained that by this action a peculiar acid was formed, to which they gave the name of *cholesteric*. The subject was again resumed by Pelletier in 1832.‡ He subjected it to an ultimate analysis and determined its constituents.

Cholesterin was treated with its own weight of concentrated nitric acid. The acid when assisted by heat speedily dissolved the cholesterin, while at the same time abundance of deutoxide of azote was evolved. When the solution cooled a yellow-coloured matter separated, and when the liquid swimming over this deposit was diluted with water, an additional portion of the same substance was separated. This yellow substance was not sensibly soluble in water; but on elevating the temperature, it swam like butter upon the surface of the water. When well washed it was deprived of all acid taste; but had a peculiar though slight stypticity. Yet it was capable of reddening litmus-paper, and of saturating the alkaline bases with considerable energy. To purify the cholesteric acid thus obtained Pelletier and Caventou proceeded in the following manner: A portion of it was

* *Diss. contin. duas observationes circa calculos, &c.* Hal. 1788, 62. As quoted by L. Gmelin, *Handbuch der Theoretischen Chemie*, ii. 504.

† Jour. de Pharmacie, iii. 292.

‡ Ann. de Chim. et de Phys. li. 189.

mixed with water and heated till the azote melted. A little carbonate of lead was now added and the mixture boiled for several hours, changing repeatedly the water. The liquids when evaporated gave all of them a little cholesterate of lead; but none of them, except the first, gave any nitrate of lead. The acid thus treated was digested in alcohol, which dissolved it, leaving the cholesterate of lead and carbonate of lead untouched. By evaporating this solution, the cholesteric acid was obtained in a state of purity.

Cholesteric acid is soluble in alcohol, and when the liquid is left to spontaneous evaporation, the acid crystallizes in white needles. But when concreted into an uncrystallized mass, its colour is orange-yellow. Its smell has some analogy to that of butter, and its taste is slightly styptic. It melts, when heated, to 136°. When heated above 212°, it is decomposed into oil, water, carbonic acid, and carburetted hydrogen. Its specific gravity is higher than that of alcohol, but lower than that of water. It is slightly soluble in water, for that liquid when left in contact with it acquires the property of reddening litmus-paper. It is more soluble in hot than in cold alcohol.

It readily combines with the bases, and forms salts. The acids have little action on it. Concentrated sulphuric acid becomes first red, and then chars it when left long in contact with it. Nitric acid dissolves it without alteration. It does not act upon it so as to produce decomposition even when boiled with it. When evaporated, the cholesteric acid remains, possessing all its properties. Acetic acid has no action on it, and is incapable of dissolving it. It is very soluble in sulphuric and acetic ethers. The volatile oils dissolve it readily even while cold, but the fixed oils do not act upon it.

From the analysis of cholesterate of barytes made by Pelletier and Caventou it follows that it is composed of

Cholesteric acid,	64· or	16·9
Barytes,	36· or	9·5
	100·	

Cholesteric acid was analyzed by Pelletier who obtained,

Carbon,	54·93
Hydrogen,	7·01
Azote,	4·71
Oxygen,	33·35
	100·00

The number of atoms which agrees best with this analysis and with the atomic weight is

		or per cent.
13 atoms carbon,	= 9·75	54·34
10 atoms hydrogen,	= 1·25 ...	6·50
½ atom azote,	= 0·875 ...	4·90
6 atoms oxygen,	= 6·0 ...	33·56
	17·875	100·

The analysis of cholesterate of strontian is considered by Pelletier as the most accurate. It was found composed of

Cholesteric acid,	100·	or 16·5
Strontian,	36·98	or 6·5

This would make the atomic weight of cholesteric acid 16·5, which does not deviate much from that obtained by the ultimate analysis.

All the *cholesterates* are more or less coloured. The alkaline cholesterates are very soluble and deliquescent, but the earthy and metalline cholesterates are very little or not at all soluble in water. They are decomposed by all the mineral and most of the vegetable acids, if we except carbonic acid. The alkaline cholesterates precipitate all the metallic solutions, and the precipitates vary in colour according to the kind of metal or the degree of its oxydizement.

1. *Cholesterate of potash* has a brownish-yellow colour, does not crystallize, is very deliquescent, and does not dissolve in alcohol or ether. It is incapable of uniting with a second dose of the acid. When this salt is decomposed by sulphuric or any other acid, the cholesteric acid separates in white flocks, which float upon the surface of the liquid. When heat is applied to this salt, the acid undergoes decomposition. There pass over water, oil, and carburetted-hydrogen gas, while carbonated-potash remains in the retort. No hydrocyanic acid is evolved during this decomposition.

2. *Cholesterate of soda* resembles the preceding salt so exactly that we can only distinguish them by separating the base, and ascertaining its nature.

3. *Cholesterate of ammonia,* obtained by directly uniting the constituents of the salt together, has the same taste, colour, and smell, as the two preceding species; and its reactions are similar.

4. *Cholesterate of barytes* is easily obtained by double decom-

position. It is very little soluble in water. When newly precipitated, it has a lively red colour; but on drying it becomes of a dark muddy red. It has neither taste nor smell. According to the analysis of Pelletier and Caventou, it is composed of

Cholesteric acid,	16·9
Barytes,	9·5

They found that cholesteric acid required for its saturation about three and a-half times as much barytes as sulphuric acid does. According to that statement, its atomic weight should only be 17·5.

5. *Cholesterate of strontian* may be obtained, like the preceding salt, by double decomposition. It has an orange-red colour, is almost insoluble in water, and is destitute of taste and smell. Pelletier and Caventou analyzed it after it had been dried in the temperature of 212°, and obtained,

Cholesteric acid,	16·5
Strontian,	6·5

6. *Cholesterate of lime* was obtained by mixing solutions of chloride of calcium and cholesterate of potash. It has a brick-red colour, is destitute of taste and smell, and is more soluble in water than the two preceding species.

7. *Cholesterate of magnesia* is obtained by double decomposition. It has a deep brick-red colour, and is insoluble in water.

8. *Cholesterate of alumina* may be obtained by mixing together solutions of alum and cholesterate of potash. When newly precipitated it has a beautiful red colour, but becomes dark and dull on drying.

9. *Cholesterate of platinum* is obtained by mixing solutions of chloride of platinum and cholesterate of potash. It has a brown colour, is insoluble in water, and very heavy.

10. *Cholesterate of silver* has an orange-red colour, which becomes dull on drying.

11. *Cholesterate of lead* was obtained by mixing nitrate or acetate of lead with cholesterate of potash. It has a deep brick-colour, but loses its beauty on drying. It is insoluble in water, but dissolves in acetic acid, or rather it is decomposed by that acid.

Pelletier and Caventou found that 100 parts of this salt yielded 100 parts exactly of sulphate of lead. Now 100 sulphate of lead contain 73·68 of oxide of lead. Hence the cholesterate of lead must be a compound of

Cholesteric acid, . . 26·32 or 5 or 17·875
Oxide of lead, . . 73·68 or 14 or 50 = 3½ atoms.

It was probably a mixture of tetrakis-cholesterate of lead and cholesterate of lead.

12. *Cholesterate of mercury.*—When cholesterate of potash is poured into proto-nitrate of mercury a black precipitate falls. The colour of the precipitate is deep-red when the mercurial salt is the per-nitrate.

13. *Cholesterate of copper.*—When cholesterate of potash is poured into any salt of copper an olive-coloured precipitate falls, without taste or smell, and quite insoluble. According to the analysis of this salt by Pelletier and Caventou it is composed of

Cholesteric acid, . . 5 or 15 = 1 atom
Oxide of copper, . . 15 or 45 = 9 atoms.

It is very unlikely that this analysis can have been made upon any thing else than a mixture. At least no analogous compound has hitherto been observed.

14. *Cholesterate of iron.*—When cholesterate of potash is poured into sulphate of iron a deep-brown precipitate falls, which is slightly soluble in water. On exposure to the air it becomes yellow by absorbing oxygen. This salt was analyzed by Pelletier and Caventou, and found composed of

Cholesteric acid, . . 11·1 or 16·65 = 1 atom
Oxide of iron, . . 4·5 or 6·75 = 1½ atom.

From this analysis it would appear that the salt was a subsesqui-cholesterate of iron.

15. *Cholesterate of Zinc* is obtained by double decomposition. It has a fine red colour, and is slightly soluble in cold water, and still more soluble in boiling water.

16. *Cholesterate of cobalt* is obtained by double decomposition, and has a yellow colour similar to that of plain Spanish snuff.

17. *Cholesterate of tin* is also yellow, but lighter, and having a tint of orange.

18. *Cholesterates of nickel and manganese* have a bistre colour.

SECTION XIV.—OF HYDROMELONIC ACID.

This acid was discovered by M. L. Gmelin in 1835, and named *hydromelonic*, because it is composed of one atom of melon and one atom of hydrogen.*

* Annalen der Pharmacie, xvi. 252.

In preparing sulpho-cyanic acid, when the mixture of prussiate of potash and sulphur had been heated too high, he occasionally got small quantities of another salt. In such cases, when the iron had been precipitated, and the filtered liquid, after having been sufficiently concentrated, was set aside, white cauliflower-looking crystals of this new salt were deposited. These being again dissolved in hot water, crystallized, exposed to pressure, and washed with hot alcohol till the salt no longer struck a red with the persalts of iron, were considered as freed from all admixture of sulpho-cyanate of potash. When this salt was dissolved in boiling water, and the solution mixed with muriatic, sulphuric, or nitric acid, a dirty-white gelatinous precipitate fell, which dried into a yellow powder. This precipitate is a hydrate of hydromelonic acid. It is slightly soluble in cold water, but more soluble in that liquid when hot. It dissolves also in alcohol. It is destitute of taste and smell, but has a feeble acid reaction. When heated it decrepitates slightly, and leaves melon, which may also be driven off by continuing the heat. It dissolves readily in nitric acid, and the solution may be evaporated without decomposing the hydromelonic acid. It dissolves also in sulphuric acid. Hydromelonate of potash effervesces when heated with nitric acid, dissolves in water, and is decomposed by acids.

To analyze this acid, Gmelin employed hydromelonate of lead, dried in the open air at 60°. 100 parts of this salt exposed to a heat of 212°, lost 11·087 parts of water; and when the heat was raised to 248°, it suffered an additional loss of 3·043; making the whole water in the salt amount to 14·13 per cent. 100 parts of the same salt being decomposed by sulphuric acid, left 62·38 of sulphate of lead, equivalent to 45·946 of oxide of lead. Hence the constituents of the salt were

Hydromelonic acid,	39·906	or 12·154 = 1 atom.
Oxide of lead,	45·964	or 14 = 1 atom.
Water.	14·130	or 3·304 = 4 atoms.
	100·000	

This analysis gives as the atomic weight of hydromelonic acid, 12·154.

Gmelin analyzed hydrous hydromelonate of lead by means of oxide of copper, and obtained

Carbon,	14·72 or 6 atoms	= 4·5	or per cent.	14·94
Hydrogen,	2·037 or 5 atoms	= 0·625	...	2·08
Azote,	23·010 or 4 atoms	= 7·0	or per cent	23·24
Oxygen,	14·269 or 4 atoms	= 4·0	...	13·18
Oxide of lead,	45·964 or 1 atom	= 14·0	...	46·46
	100·000	30·125		100·

But it is clear from the preceding analysis, that the salt thus analyzed contained 14·13, or 4 atoms of water. Subtracting this there remain for the constituents of hydromelonic acid

6 atoms carbon,	= 4·5
1 atom hydrogen,	0·125
4 atoms azote,	= 7·000
	11·625

Thus it appears that hydromelonic acid is composed of

1 atom melon, (C^6 Az^4)	= 11·5
1 atom hydrogen,	= 0·125
	11·625

Hydromelonate of Potash is a yellowish white opaque cohesive mass, having a bitter taste. When heated, it gives out carbonate and hydrocyanate of ammonia, and melts into a clear yellow liquid, which concretes on cooling. When heated with nitric acid it froths, but without effervescence. It dissolves in hot sulphuric acid, and is again precipitated by water. It is scarcely soluble in cold, but very soluble in hot water. Alcohol scarcely acts upon it, even at a boiling temperature. It is decomposed by all the strong acids, hydromelonic acid being disengaged. The earthy alkaline salts, earthy salts, and most of the metalline salts occasion a precipitate in hydromelonate of potash, consisting of flocks most commonly white. But the salts of oxide of chromium give a bluish white; those of peroxide of iron, a light brown; those of oxide of cobalt, a rose red; those of oxide of nickel, a bluish white; those of suboxide of copper, a whitish yellow; those of black oxide of copper, a sisken green; those of oxide of gold, a yellowish white; and those of oxide of platinum, a brownish yellow precipitate.

It has been ascertained that when hydromelonic acid is heated in contact with a metallic oxide, water is formed, and the melon unites with the metal, constituting a *melonet*. The only one of

these melonets hitherto examined is the *melonet of potassium.* It may be formed by fusing sulphocyanate of potash in a porcelain crucible at a red heat, adding melon as long as an evolution of bisulphuret of carbon and sulphur is observed. A brown opaque glassy mass is obtained, which, being dissolved in boiling water, and the solution allowed to cool, deposits hydrated crystals of melonet of potassium. It may be formed also by fusing five parts of butter of antimony with eight parts of sulphocyanate of potash, and removing by boiling water the soluble portion of the residue, after the sulphur and bisulphuret of carbon have been driven off.

It crystallizes from its aqueous solution in fine needles, which collect into large flocks. A concentrated solution congeals into a white mass, not easily dissolved in cold water. The crystals contain water of crystallization, which they lose when heated. They then fuse without loss of weight into a transparent yellow glass. The solution of this compound is tasteless, and precipitates all earthy and metalline salts.

SECTION XV.—OF CEREBRIC ACID.

This substance, which constitutes an important constituent of the brain, was first noticed by Vauquelin in his chemical analysis of the brain, published in 1812.* He gives it the name of *white fatty matter;* but did not obtain it in a state of purity; Kühn also noticed it under the name of *myelocone.* † Couerbe, in 1834, obtained it also, though not in a state of complete purity, and gave it the name of *cerebrote.* ‡ In 1841 it was again examined by Fremy, § who brought it to a state of comparative purity, discovered its acid properties, and gave it the name of *cerebric* acid.

Couerbe's method of obtaining it was to digest the matter of brain in ether, till every thing soluble in that liquid was removed, the residue was treated with boiling alcohol, as long as any thing continued to dissolve. The alcohol, on cooling, deposited a white matter consisting chiefly of cerebrote and cholesterin. Cold alcohol dissolved the latter of these substances, and left the cerebrote. But Fremy ascertained that cerebrote obtained in this way still contained sensible quantities of cerebrate of lime

* Ann. de Chim. lxxxi. 37, or Annals of Philosophy, i. 332.

† Dissert. de Cholestearine, p. 20. ‡ Ann. de Chim. et de Phys. lvi. 171

§ Jour. de Pharmacie, xxvii. 439.

and albumen. He succeeded in obtaining it pure by the following process.

He digested the mass obtained by evaporating the etherial solution of the brain in a great quantity of ether. By this means a white substance is precipitated, which is isolated by decantation, and which, when exposed to the air, is transformed into a waxy and fatty matter. This precipitate contains cerebric acid, often combined with phosphate of lime, or soda, and with albumen. It was dissolved in boiling absolute alcohol slightly acidulated by sulphuric acid. The sulphates of lime and soda, with some albumen, remained in suspension, and were separated by the filter. The cerebric and oleophosphoric acids were held in solution, and were deposited as the liquid cooled. The precipitate was washed with cold ether, which dissolved the oleophosphoric acid, and left the cerebric. Finally, the cerebric acid was dissolved in boiling ether, and crystallized three or four times. It was then pure.

Thus obtained it is white, and composed of small crystalline grains. It is entirely soluble in boiling alcohol, almost insoluble in cold ether, but more soluble in that liquid when boiling hot. It has the remarkable property of swelling like starch in boiling water, though it is quite insoluble in that liquid. When strongly heated it melts, but its fusing point is very little lower than that at which it undergoes decomposition.

When heated in the open air it burns, giving out a characteristic odour, and leaving a charcoal which burns with difficulty, and which is sensibly acid. Sulphuric acid blackens it. Nitric acid decomposes it very slowly. When calcined with nitre and carbonate of potash, no sulphate of potash is formed; a proof that it contains no sulphur. But phosphoric acid is always formed in such quantities as may be determined.

When heated with an excess of potash, ammonia is disengaged, proving the presence of azote.

This acid was analyzed by Fremy in the usual way. He found the constituents to be

Carbon, .	66·7
Hydrogen, .	10·6
Azote, .	2·3
Phosphorus, .	0·9
Oxygen, .	19·5
	100·0

To determine its atomic weight, he analyzed cerebrate of barytes, which he had obtained in the following manner:—Cerebric acid was boiled with water to convert it into a hydrate. An excess of barytes water was then poured into the liquid, and it was kept boiling for some time, taking care to exclude carbonic acid gas. A white, flocky insoluble precipitate fell, which, when washed and dried, was composed of

Cerebric acid, .	92·2 or	112·29
Barytes, . .	7·8 or	9·5
	100·0	

Were we to consider the salt as a neutral cerebrate, the atomic weight of cerebric acid would be 112·29. But it is more probable from analogy that it contains two atoms barytes united to one atom of cerebric acid. This would make the atomic weight of the acid 224·58.

The atomic composition agreeing best with this weight, and with Fremy's analysis is

198 atoms carbon, .	= 148·5 or per cent.	66·90
186 atoms hydrogen, .	= 23·25 ...	10·47
3 atoms azote, .	= 5·25 ...	2·36
1 atom phosphorus, .	= 2· ...	0·90
43 atoms oxygen, .	= 43. ...	19·37
	222·	100·00

or perhaps 3 (C^{66} H^{63} Az O^{14}) + Ph. These numbers correspond sufficiently with the analysis, and make the atomic weight of the acid 222.

Cerebric acid combines in definite proportions with bases. It is therefore an acid, though possessed of very little energy. When heated with dilute solution of potash, soda, or ammonia, it is not dissolved; yet it combines with their different bases. These combinations may be obtained by putting an alcoholic solution of cerebric acid in contact with these bases. A precipitate immediately falls, almost quite insoluble in alcohol, which consists of the acid united to the respective bases. Lime, barytes, and strontian combine directly with cerebric acid, and make it lose the property of forming an emulsion with water. The remaining cerebrates have not yet been examined.

SECTION XVI.—OF OLEOPHOSPHORIC ACID.

The presence of this acid in the human brain, and doubtless in that of the inferior animals, has been lately discovered by M. Fremy.*

It has been stated in the preceding section, that when the etherial product of the brain is treated with ether, there remains in solution a viscid substance which contains oleophosphoric acid, frequently combined with soda. To obtain the acid we must decompose this salt with an acid, and digest the mass in boiling alcohol, which dissolves the oleophosphoric acid, and lets it precipitate as it cools. Thus obtained it is always mixed with olein, which may be removed by anhydrous alcohol. We may free it from cholesterin, which is often present, by alcohol and ether, which dissolve the cholesterin more readily than the oleophosphoric acid. It has not yet, however, been obtained in a state of purity. Fremy was not able to free it completely from cholesterin and cerebric acid.

It has usually a yellow colour, like olein. It is insoluble in water, and swells a little when put into boiling water. It is always viscid. In cold alcohol it is insoluble, but dissolves readily in that liquid when at the boiling temperature. It is soluble in ether.

When placed in contact with potash, soda, or ammonia, it immediately forms soapy compounds similar to the matter extracted from brain when treated with ether. With the other bases it forms compounds insoluble in water. When oleophosphoric acid is burnt in the open air, it leaves a strongly acid charcoal, in which the presence of phosphoric acid may be detected.

When this acid is boiled for a long time in water or alcohol, it gradually loses its viscidity, and is changed into a fluid oil, which possesses the characters of pure olein. The water or alcohol holds a notable quantity of phosphoric acid in solution. This decomposition is very slow and incomplete when the oleophosphoric acid is treated with pure water or alcohol, but becomes very rapid when these liquids are rendered slightly acid. It takes place at the common temperature, but very slowly. The atmosphere has no share whatever in this decomposition.

Olein is soluble in absolute alcohol, but oleophosphoric acid is quite insoluble in that liquid. This shows that oleophosphoric

* Jour. de Pharm., xxvii. 463.

acid is not a mere mixture of olein and phosphoric acid, but a compound of the two. But after the oleophosphoric acid has been boiled in water or alcohol, the olein being separated from the acid, is readily taken up by absolute alcohol, even without the application of heat. The olein thus disengaged burns upon platinum foil without leaving any residue, which is not the case with oleophosphoric acid.

From these facts it is obvious that oleophosphoric acid is very easily altered in its nature. Hence the reason why it is frequently found in a brain quite fresh; though no traces of it can be discovered after the brain has been left for some time to putrefy; but instead of it, much olein and phosphoric acid in a separate state. M. Fremy is of opinion that this tendency to decomposition may account for some of the changes which are apt to take place in a living brain.

Oleophosphoric acid is readily acted on by fuming nitric acid. Phosphoric acid is dissolved, and a fatty acid swims on the surface of the liquid. The quantity of phosphoric acid determined in this way varies from 1·9 to 2 per cent.

The alkalies added in excess transform the oleophosphoric acid into oleates, phosphates, and glycerin.

Fremy considers oleophosphoric acid to be a compound of phosphoric acid and olein. But he could not succeed in his attempts to combine these two bodies artificially. It must be acknowledged that such a compound, if it do exist, is of a very singular nature. Olein is a compound of oleic acid and glycerin, in reality a salt, while phosphoric acid is a powerful acid.

SECTION XVII.—OF NITROLEUCIC ACID.

This acid was discovered by Braconnot in 1820.* When minced animal muscle is digested in water till everything soluble is removed, and, after being exposed to pressure, is mixed with its own weight of concentrated sulphuric acid, it swells up and dissolves and a little fatty matter swims on the surface, which must be removed. This mass being mixed with twice its weight of water and boiled for nine hours, taking care to add water as fast as it evaporates, the muscle undergoes decomposition. Ammonia is formed, which unites with the sulphuric acid, while from the other constituents of the muscle at least three new principles

* Ann. de Chim. et de Phys. xiii. 118.

are formed. These three may be separated from each other in the following way. Saturate the acid liquid with carbonate of lime, and filter in order to get rid of the sulphate of lime formed, and then evaporate to dryness. A yellowish mass remains, having the flavour of boiled meat. If we boil this matter with alcohol of 0·845, two of the three principles are dissolved. The alcoholic solutions are mixed and distilled. The residue taken out of the retort is evaporated to dryness, and what remains is treated with a small quantity of alcohol of 0·83. An extractive looking substance is dissolved, which attracts moisture from the air, and has the smell and taste of roasted meat.

The portion insoluble in alcohol of 0·83 has been called by Braconnot *leucin* (from λευκος, *white.*) It is a white powder soluble in water and crystallizable. It generally contains some foreign matter, from which it may be freed by cautiously adding solution of tannin. If, after filtering, we evaporate till a pellicle begins to appear on the surface, and then leave it at rest, a great number of small round grains are deposited, flat, and having an elevated margin so as to resemble some buttons. These crystals are leucin.

Leucin crackles under the teeth; its taste resembles that of boiled meat. When heated to 212° it melts and undergoes a partial decomposition, giving out at the same time the smell of roast meat. One portion sublimes unaltered in the form of small white opaque crystalline grains, while at the same time there comes over into the receiver ammoniacal water and a little empyreumatic oil. Leucin is very soluble in water and but little soluble in alcohol. But hot alcohol dissolves a greater portion than it can retain when cold. The aqueous solution of leucin is not precipitated by diacetate of lead nor by any metalline salt, except pernitrate of mercury, which throws it down completely in the state of a white magma, while the supernatant liquor becomes red.

To obtain nitro-leucic acid the leucin is to be dissolved in nitric acid by means of a gentle heat. A slight effervescence takes place, but no red vapours appear. When sufficiently concentrated the liquid concretes into a mass of white crystals. When freed from nitric acid by pressure between the folds of blotting-paper and purified by a second crystallization, these crystals constitute *nitroleucic* acid.

Its taste is sour but weak. It combines with bases and forms salts called *nitroleucates*. Only two of them, nitroleucate of lime

and of magnesia, have been examined by Braconnot. They crystallize and do not absorb moisture from the atmosphere.

It would be an object of some consequence to examine this acid more in detail. It is probably analogous to the compound acid described in the Chemistry of Vegetable Bodies, p. 168.

CLASS II.

OF ANIMAL BASES.

THESE bodies have been hitherto but imperfectly examined. The number of animal bodies which are known to combine and neutralize acids does not exceed eleven, and, if we except *urea*, not one of them has hitherto been subjected to an ultimate analysis. It is true, indeed, that *ammonia* is obtained from the animal kingdoms, and that it is a very decided base. But, for reasons too obvious to require being stated here, that alkali was described while treating of the chemistry of inorganic bodies. Here, therefore, we shall simply give a list of the principal combinations into which it enters.

CHAPTER II.

OF UREA.

THE substance now known by the name of *urea* was discovered by Rouelle Junr., during his researches on *urine*, which were published in the *Journal de Medecine* for 1773 and 1777. He obtained it by evaporating recent urine to dryness and digesting the residue in alcohol. The *urea*, which he distinguished by the name of *soapy matter*, was dissolved. By proper evaporation it was obtained in crystals. He mentions that it is difficult to obtain it in a dry state, and that it absorbs moisture from the atmosphere. When heated, it yielded, he says, much more than half its weight of carbonate of ammonia.* In 1808 a new set of experiments was made upon it by Fourcroy and Vauquelin.†

* Macquer's Dictionnaire de Chimie (second edition), ii. 645.

† Ann. de Mus. d'Hist. Naturelle, ii. 226.

They give a process for procuring it, and describe its properties at considerable length, though they did not succeed in obtaining it in a state of purity.

In the year 1798, Dr Rollo published his cases of *Diabetes Mellitus.* To the second edition of this work was added an appendix by Mr Cruikshanks of Woolwich on Urine. In this very important paper Mr Cruikshanks, who seems to have been ignorant of what Rouelle had done, describes urea anew, and gives a much more detailed account of its properties. Fourcroy and Vauquelin take no notice of Cruikshanks in their paper, and might have been supposed ignorant of the discoveries of the British chemist, had not Fourcroy added copious notes to the French translation of Rollo's work, and must therefore of necessity have been acquainted with that book. In his *Systeme de connaisançes Chimiques,* published about the beginning of the present century, he notices Cruikshanks's discoveries, and particularly the property which urea has of combining and crystallizing with nitric acid; but blames him for calling it *animal extractive matter* instead of distinguishing it by a peculiar name. In the elaborate paper upon Urine by Fourcroy and Vauquelin, published in 1800,* they notice Cruikshanks's discoveries; but assure their readers that they had discovered urea and ascertained its characters, a whole year before they became acquainted with Rollo's work, in consequence of the notice of it in the *Bibliotheque Britannique.*

Neither Rouelle, Cruikshanks, nor Fourcroy and Vauquelin, had obtained urea in a state of purity. But in 1808 Berzelius published the second volume of his *Djurkemien* in which he describes a process, rather complicated indeed, but successful, by which he obtained it in a state of purity, and was enabled to determine its properties.† But, as this book was written in the Swedish language, the discovery of Berzelius remained unknown till his *View of the Progress and present State of Animal Chemistry* was published in English in 1813.

In 1818, Dr Prout published his *Observations on the Nature of some of the Proximate principles of Urine.*‡ In this important paper he gives a much easier and shorter process for obtaining

* Ann. de Chim. xxxi. 48, and xxxii. 80.

† Föreläsningar i Djurkemien, ii. 279.

‡ In the eighth volume of the Medico-Chirurgical Transactions.

pure urea than that of Berzelius, with which, indeed, he was unacquainted. He described the properties of pure urea and subjected it to an accurate ultimate analysis. An analysis had been previously made by Berard and another by Prevost and Dumas; both of which approached very near the results obtained by Prout, except in the hydrogen, of which they obtained a great excess, because their urea had not been freed from water. More lately Wöhler made the curious discovery, that urea may be made artificially by uniting together *cyanic acid* and *ammonia.** He described also the phenomena which take place when urea is exposed to a high temperature.† He showed likewise that urea is obtained when uric acid is distilled.‡ Berzelius, in the seventh volume of the French translation of his *Traité de Chimie,* gives a new process for obtaining *urea.* It seems merely a modification of that of Prout.

The process of Dr Prout is the following: Evaporate by a gentle heat a quantity of fresh urine to the consistence of a syrup. Allow it to cool, and add by degrees pure concentrated nitric acid till the whole assumes the form of a crystallized mass, having a deep brown colour. Let this mass be washed with a little cold water, and left to drain, then pour upon it slowly a pretty concentrated solution of carbonate of potash or soda till it is completely neutralized. Concentrate the liquid by a cautious evaporation, and set it aside till the nitre formed is deposited in crystals. Separate the liquid portion from these crystals, and add to it enough of animal charcoal to reduce the whole to the state of a thin paste. Let the mixture remain at least for some hours, and then pour upon it a sufficient quantity of cold water to separate the urea. Evaporate the colourless liquor to dryness by a gentle heat and then boil the residue in very strong alcohol, which will dissolve the urea, but leave the nitre and most other saline substances behind it. By evaporating the alcoholic solutions we obtain the urea in crystals, and two or three solutions in alcohol and crystallizations are sufficient to bring it to a state of purity.

The process of Berzelius is as follows: Evaporate the urine to the consistency of a syrup, and then dry it over the steam-bath

* Poggendorf's Annalen, xii. 253.

† Jour. de Pharmacie, xvi. 298, or Poggendorf's Annalen, xv. 619.

‡ Poggendorf, ibid. p. 529.

as completely as possible. Treat the residue with absolute alcohol till every thing which that liquor is capable of taking up is dissolved. Distil the alcoholic solution over the steam-bath. Dissolve the residue in a little water, and digest it with a little animal charcoal, which will render it nearly colourless. Filter the liquid. Heat it to 122°, and dissolve in it as much oxalic acid as it is capable of taking up at that temperature. On cooling colourless crystals of oxalate of urea are deposited. By evaporating the residual liquid in a gentle heat we obtain more oxalate of urea. When it begins to thicken and has no longer a strong acid taste, we may obtain a great deal more oxalate of urea by heating it to 122°, and adding a new dose of oxalic acid. Collect the whole crystals thus obtained and wash them with a little cold water. Then dissolve them in boiling water, adding a small quantity of animal charcoal, filtrate and evaporate. Oxalate of urea is deposited in crystals as white as snow. Dissolve these crystals in water and mix it with carbonate of lime in very fine powder, which decomposes the oxalate of urea with effervescence. When the liquor no longer reddens litmus-paper, let it be filtered to get rid of the oxalate of lime, and evaporate the clear liquid over the water-bath. We obtain a white mass of a saline appearance, which is urea, but still mixed with an alkaline oxalate. This oxalate is removed by digesting the saline mass in absolute alcohol. Nothing is dissolved but pure urea. What remains is a chemical combination of urea and an alkaline oxalate, usually oxalate of ammonia.

Liebig has lately given another process, which he says is less expensive, and which is merely the method used by Wöhler to convert cyanate of ammonia into urea.*

Twenty-eight parts of dry prussiate of potash are mixed with 14 parts of peroxide of manganese in powder, and the mixture is made as intimate as possible. This mixture is heated on a plate of iron over a charcoal fire to a dull red heat. It takes fire, but is gradually extinguished, and it must be well stirred while cooling to prevent agglutination and to facilitate the admission of air. When cold it is digested repeatedly in cold water, and the solution is mixed with 20½ parts of sulphate of ammonia. The first concentrated liquid obtained by washing the precipitate should be set aside, and the sulphate of ammonia dis-

* Ann. der Pharm. xxxviii. 108.

solved in the succeeding weak liquids. A copious precipitate of sulphate of potash falls. The supernatant liquid is decanted off and evaporated over the water-bath. More sulphate of potash falls, which is separated, and this is repeated as long as the sulphate continues to form. The liquid is now evaporated to dryness, and the solid residue is digested in boiling alcohol of 80 or 90 per cent. The urea is dissolved. It crystallizes as the alcohol cools or is evaporated. By this process a pound of prussiate of potash will furnish one-third of a pound of urea, colourless and crystallized.

The precipitate of potash when heated with black oxide of manganese is converted into cyanate of potash, a salt very soluble in water. When the solution of this salt is mixed with sulphate of ammonia, sulphate of potash and cyanate of ammonia are formed, which last by a gentle heat, as Wöhler first discovered, is converted into urea.

Urea when pure and in crystals is white and transparent. It has no smell, but a cooling taste, and its lustre is pearly. When deposited from a concentrated hot solution it is in the form of fine needles; but by spontaneous evaporation it assumes the form of long, narrow four-sided prisms. It is best obtained in crystals by allowing a boiling-hot saturated alcoholic solution to cool slowly. It produces no change on vegetable blues. It is not affected by exposure to the air, unless the atmosphere be very moist, when it deliquesces slightly, but is not decomposed. When heated it melts, one portion is decomposed and another sublimed without any apparent change. The specific gravity of its crystals, as determined by Prout, is 1·350.

At the temperature of 60°, water dissolves more than its own weight of urea. The solution exposed to the air for some months underwent no alteration. Boiling water dissolves any quantity whatever of urea, and the urea is not altered at that temperature.

At the ordinary temperature alcohol of 0·816 dissolves the fifth part of its weight of urea, and when boiling hot it dissolves more than its weight of it. On cooling the additional quantity is precipitated in crystals. It is hardly soluble in ether and oil of turpentine, though it renders these liquids opaque.

The fixed alkalies and the alkaline earths decompose urea, especially when assisted by heat and when water is present. It combines with most of the metallic oxides. Its combination with

oxide of silver is grey. This compound detonates when heated and the oxide is reduced. But urea does not seem capable of decomposing any of the metallic salts. We can only combine it with the oxides by double decomposition. The best way of obtaining these compounds is to mix a solution of a metallic salt with a concentrated solution of urea, and to add as much alkali as will saturate the acid of the metallic salt. We may combine urea with oxide of lead by digesting the oxide in a concentrated solution of urea.

Nitric acid forms with urea a compound which crystallizes in large brilliant plates or transparent prisms, though it is very difficult to obtain the compound in regular crystals. These crystals have an acid taste, and are not altered by exposure to the air. At the temperature of 50° 100 parts of water dissolve 19·7 parts of nitrate of urea. This salt was found by Dr Prout's analysis to be composed of,

Nitric acid, . .	6·75
Urea, . . .	*7·45
	14·2

When heated in a retort it gives out a combustible gas,† and is converted into nitrate of ammonia. When heated rapidly on platinum foil it detonates. A good deal of cold is produced when nitrate of urea is dissolved in water. When the aqueous solution is boiled an effervescence takes place and carbonic acid is disengaged. There remains a solution of carbonate and nitrate of ammonia.

Dr Prout discovered that oxalic acid forms a crystalline compound with urea as well as nitric acid. Oxalate of urea is in long slender plates. Its taste is cooling. When heated it melts and boils, carbonate of ammonia is disengaged and cyanuric acid is formed. Oxalate of urea dissolves in much greater quantity in boiling than in cold water, and is deposited in crystals as the

* There is probably another compound of nitric acid and urea. I obtained a compound of nitric acid, 6·75; urea, 17·23, or rather more than twice the urea stated in the text. In this case the urea was not deprived of its colouring matter, and therefore was heavier than it ought to have been. Had it been pure it would in all likelihood not have exceeded fifteen, or double the quantity which Prout obtained.

† Probably *cyanogen*.

liquid cools. At 61° 100 parts of water dissolve only 4·37 of oxalate of urea. It is still less soluble in alcohol than in water. One hundred parts of alcohol of 0·833 dissolves only 1·6 of oxalate at the temperature of 61.° According to the analysis of Berzelius this salt is composed of,

Oxalic acid,	37·436 or 4·5
Urea,	62·564 or 7·525
	100·000

It contains no water of crystallization. According to Berzelius this salt is capable of combining with the neutral alkaline oxalates, forming double salts, which are soluble in alcohol. Lime decomposes these salts in such a way that oxalate of lime precipitates, while the urea and alkaline oxalate remain in solution.

When cyanuric acid is boiled with a concentrated solution of urea, and the solution filtered while hot, fine needles are deposited as the solution cools. These are composed of cyanuric acid and urea. The same salt is obtained when uric acid is distilled in a retort. It is soluble in alcohol. Nitric acid decomposes it, nitrate of urea being formed, and cyanuric acid set at liberty.

MM. Cap and Henri, by treating lactate of lime with oxalate of urea, obtained lactate of urea, which crystallizes in white prismatic needles. They have extracted the same salt from urine. They separated the free lactic acid from urine by an excess of hydrate of zinc, and obtained lactate of urea identical with that prepared by direct combination.* Urea possesses the property of a base, and combines not only with nitric, oxalic, and lactic acid, but also with sulphuric acid. Sulphate of urea may be obtained by mixing 100 parts of oxalate of urea with 125 parts of sulphate of lime in silky crystals, adding a little water and heating for an instant. Add four or five volumes of alcohol, of specific gravity 0·843, filter and evaporate. The sulphate of urea crystallizes in grains and needles; its taste is sharp and cooling.

When common salt is dissolved in urine, it crystallizes in octahedrons, while sal-ammoniac, under the same circumstances, crystallizes in cubes. This alteration in the shape of the crystals is ascribed to the salts entering into combination with urea.

* Phil. Mag. third series, xiii. 478; or Jour. de Pharm. xxv. 133.

Urea is not precipitated from its solutions by any metallic salt nor by tannin.

Urea was subjected to an ultimate analysis by Berard and by Prevost and Dumas, but the proportion of hydrogen obtained by these chemists was greatly in excess. It was analyzed by Dr Prout in 1818,* with great precision. He obtained

Carbon,	19·99
Hydrogen,	6·66
Azote,	46·66
Oxygen,	26·66
	100·

In Dobereiner's supplement it is stated that Wöhler and Liebig made two analyses of urea with the following results:

Carbon,	20·02	20·20
Hydrogen,	6·71	6·60
Azote,	46·73	46·76
Oxygen,	26·54	26·44
	100·00	100·00

I do not know where these analyses were published. But it is obvious at a glance that they coincide most satisfactorily with the results previously obtained by Dr Prout.

Some idea of the atomic weight of urea may be formed from the constitution of nitrate of urea and oxalate of urea. The former gives 7·45, and the latter 7·52, the mean of which is 7·485. Now, if its atomic weight be 7·5, its constitution must be

2 atoms carbon,	= 1·5	or per cent.	20·00
4 atoms hydrogen,	= 0·5	...	6·66
2 atoms azote,	= 3·5	...	46·66
2 atoms oxygen,	= 2·0	...	26·66
	7·5		100·

which corresponds exactly with the analysis of Dr Prout.

Wöhler discovered that when a solution of sal-ammoniac is poured upon *cyanate of silver* recently precipitated, chloride of silver is formed, and instead of cyanate of ammonia, which ought to be formed, if we evaporate the solution we get white crystals,

* Annals of Philosophy, first series, xi. 353.

possessing the characters of urea. It is obvious that the constituents of urea and of cyanate of ammonia are identical.

Urea is . $C^2 H^4 Az^2 O^2$.

Cyanate of ammonia, $C^2 Az O + H^3 Az + H O$.

At first cyanate of ammonia actually exists in the liquid. But by the evaporation, the constituents of this salt arrange themselves in a different manner, and constitute the more stable compound, urea. The difference between the properties of cyanate of ammonia and urea is very great, yet the ultimate constituents of both are the same. We see here strikingly exemplified how entirely the properties of substances depend upon the way in which the ultimate atoms are arranged.

Urea some years ago was introduced in France in medicine as a *diuretic.* But I have never seen any well attested evidence that it really possesses diuretic properties. Urea is not confined to the urine. It has been detected in the blood and in the liquor of dropsy.

CHAPTER II.

OF ODORIN.

When animal substances are distilled, one of the constant products is an empyreumatic oil, usually called *Dippel's animal oil,* because that chemist was the first who obtained it in a state of purity.* Unverdorben examined this oil in the year 1826,† and extracted from it four different salifiable bases, which he distinguished by the name of *odorin, animin, olanin, and ammolin.*

Rectified Dippel's oil is composed of these four substances. *Odorin* may be obtained from the rectified oil by the following process: Saturate the ammonia in the oil till the alkaline reaction is destroyed; but care must be taken not to add more than is sufficient for that purpose. Then distil the oil over the steam-bath without adding any water to it. What comes over first is

* He made it known as a medicine in 1711, in a pamphlet, published at Leyden. All animal substances, he says, yield it. He purified it by 30 successive rectifications.

† Poggendorf's Annalen, viii. 253.

odorin. Examine what comes over from time to time, by letting a drop of it fall into water. As long as it dissolves completely in the water, it is pure odorin, but as soon as it begins to render the water muddy, we may conclude that *animin* is coming over also. We must then change the receiver that we may not injure the purity of the odorin, which has already distilled over. If we continue the distillation till only one-twentieth of the oil remains in the retort, we obtain a mixture of odorin and animin. The last 20th is a mixture of animin and olanin.

Odorin* is a colourless oil, which refracts light very powerfully. It has a peculiar and disagreeable odour, differing from that of Dippel's oil. Its taste is acrid and peculiar. It restores the blue colour of litmus-paper reddened by an acid. It boils at about 212°, and does not become solid though cooled down to —13°.

It is very soluble in water, alcohol, ether, and the volatile oils. It combines with the acids and forms salts. It dissolves the resins, and the compounds formed with them are decomposed when the solution is distilled with water. It combines also with various extractive matters so intimately that it cannot be separated from them by distillation. But these compounds are decomposed by the more powerful salifiable bases.

All the salts of odorin have the form of oils; and they have little stability. A portion of the odorin makes its escape, and a subsalt remains, or even the acid alone, if it is feeble and fixed. The nitrate, muriate, and acetate of odorin may be distilled over along with water. Odorin is separated from its combination with acids by almost all the other bases. The few observations made upon the salts of odorin by Unverdorben, the only person who hitherto has examined them, are the following:

1. *Sulphate of odorin.*—When we mix concentrated sulphuric acid with more odorin than it can saturate, the mixture becomes boiling hot. The sulphate precipitates under the form of a heavier oil, through the excess of odorin, which does not dissolve it. This sulphate is very soluble in water. When we distil or evaporate it a portion of the odorin escapes, and a supersulphate of odorin remains.

2. *Sulphite of odorin* is formed when odorin is made to absorb sulphurous acid gas. Heat is evolved, and an oily salt

* Unverdorben, Poggendorf's Annalen, xi. 61.

formed, which may be distilled over without alteration. It is very soluble in water, and when exposed to the air absorbs oxygen, and is converted into sulphate. Acids decompose it with the evolution of sulphurous acid gas.

3. *Nitrate of odorin* may be distilled over; but it undergoes a partial alteration during the process. What comes over is a mixture of nitrate and nitrite of odorin, together with an empyreumatic oil. The residue in the retort, besides undecomposed salt, consists of an extractive matter and a resin soluble in potash.

4. *Carbonate of odorin* is a volatile oil.

5. *Borate and benzoate of odorin* when exposed to the air, let go by far the greatest part of their base; but retain a small portion of it with considerable force.

6. Unverdorben did not succeed in his attempts to combine odorin with *arsenious* acid.

7. *Muriate of odorin* may be formed by causing the base to absorb the acid in the gaseous state. It is a colourless oil, which does not become solid though cooled down to —13°. It may be distilled over without decomposition, and is very soluble in water.

When a current of *chlorine* is passed through odorin, decomposition takes place, muriate of odorin is formed, but the greatest part of the liquid is converted into a thick yellow magma. About two-thirds of the odorin is converted into this matter, while the remaining third becomes muriate. The yellow magma is partly soluble in potash, from which it is precipitated by acids in the state of a yellowish-brown powder. The portion insoluble in potash is a resinous-looking substance, fusible and soluble in concentrated sulphuric acid.

Muriate of odorin has a brownish-yellow colour, and is soluble in water, alcohol, and ether. When distilled odorin passes over, and a supersalt remains in the retort.

8. When *iodine* is added to odorin, a powder is formed, having a brown colour, and insoluble. There is formed at the same time an extractive-looking substance, soluble in ether, and precipitated by the salts of lead and silver.

9. The double salts of odorin have more fixity and a stronger resemblance to the common class of salts than the simple salts.

Sulphate of copper is dissolved by odorin, and the solution has an intense blue colour. A subsalt of sulphate of copper re-

mains, showing that sulphate of odorin and copper has been formed. By evaporation we obtain it of a green colour; and the excess of odorin may be gradually driven off.

Acetate of copper behaves with odorin in the same way as sulphate. When we mix an aqueous solution of this salt with odorin, no precipitate falls, and when the mixture is left to spontaneous evaporation, in proportion as the excess of odorin is volatilized, a double subsalt is deposited in four-sided short prisms, having a grass green colour. This salt does not lose its odorin though exposed to the air. It is soluble in water and alcohol, but insoluble in ether. When distilled, odorin comes over first, then acetate of odorin, and there remains in the retort acetate of copper, mixed with brown subacetate, which has precipitated.

Neither oxide of copper nor carbonate of copper is soluble in odorin.

When a solution of *corrosive sublimate* is mixed with muriate of odorin, the two salts combine together, and when we evaporate the liquid, an *oil* precipitates limpid-like water. This oil is a double salt not altered by exposure to the air. When we mix a solution of corrosive sublimate with a solution of odorin, a subsalt precipitates in the form of a crystalline powder, which is soluble in ten times its weight of boiling water, and which is mostly deposited in crystals as the solution cools. If we boil the solution, the odorin escapes with the steam, and nothing remains but the corrosive sublimate. The anhydrous salt behaves in the same way. It is soluble in alcohol and ether, and is slowly decomposed when exposed to the air.

When *chloride of gold* is mixed with muriate of odorin, a double salt precipitates in small yellow crystals, soluble in twenty times their weight of boiling water. The solution of this salt reddens litmus-paper. It is more soluble in alcohol than in water, and is insoluble in ether. It may be fused, but in that case is easily decomposed into muriate of odorin, chlorine, and metallic gold; dilute acids dissolve it at a boiling temperature, and it is again deposited unaltered as the liquid cools.

When odorin is mixed with chloride of gold, a yellow saline powder precipitates, which is a double subsalt almost insoluble in cold water, slightly soluble in boiling water, but again precipitated as the solution cools. It is not altered by exposure to the air, and may be fused without undergoing decomposition.

After cooling, it is yellow and transparent. When exposed to a stronger heat, muriate of odorin may be distilled over, leaving metallic gold with some other products of decomposition in the retort. Nitric acid scarcely dissolves it even at a boiling heat.

Chloride of platinum gives with muriate of odorin a double salt, which crystallizes, has a yellow colour, and is soluble in four times its weight of water. With odorin alone it forms a subsalt, which is very little soluble, and which precipitates under the form of a powder. Boiling water dissolves a small quantity of it, which is deposited as the solution cools. The action of these two double salts upon reagents is similar to that of the two corresponding salts of gold.

CHAPTER III.

OF ANIMIN.

It was stated in the last chapter, that when rectified *oil of Dippel*, saturated with ammonia, was subjected to distillation, the first liquid which came over was pure odorin. As soon as the liquid which distils begins to render water muddy, a new receiver is applied, and the distillation continued, till only one-twentieth of the original quantity remains in the receiver. The liquor thus obtained is a mixture of odorin and *animin*. If we agitate it with a little water, the odorin will be dissolved, together with a little animin. We may extract the odorin from this solution by supersaturating the liquid with sulphuric acid, evaporating the solution, and distilling the residue with a base. The *animin* remains under the form of an oil. It has a peculiar smell. It is soluble in twenty times its weight of cold water, but it is much less soluble in hot water. Hence it happens that the cold solution becomes milky when heated, and resumes its limpidity again when allowed to cool. The solution changes reddened litmus-paper to a violet blue colour. It is very soluble in alcohol, ether, and oils.

Its affinity for acids seems nearly the same as that of odorin. Its salts resemble oils like those of odorin; but they are much less soluble in water.

1. *Sulphate of animin* is an oily body very little soluble in

water. When we boil it with water, a portion of the animin is volatilized, and there remains a supersalt very soluble in water and alcohol, and which undergoes no farther change, though the boiling be prolonged.

2. *Benzoate of animin* is little soluble in cold water, but more soluble in hot water, by which it is not so easily decomposed as benzoate of odorin.

3. *Muriate of Animin* forms double salts with the chlorides of copper, gold, and platinum. The double chloride of animin and mercury has the form of a colourless oil, that of chloride of animin and gold the form of a brown oil, while the chloride of animin and platinum crystallizes. All these double salts are very little soluble in water.*

CHAPTER IV.

OF OLANIN. †

It has been already stated, in the preceding chapters, that when rectified Dippel's oil is distilled to one-twentieth part, what passes over is odorin and animin. The twentieth that remains is chiefly *olanin;* though it still retains a portion of animin. If we agitate this residue four times successively with five times its weight of water, the animin will be dissolved by that liquid, and the olanin will remain in a state of purity.

It is an oily liquid, somewhat thick, and resembling a fat oil. It has a peculiar but not a disagreeable odour, and reacts very feebly as an alkali upon reddened litmus-paper. When exposed to the air it becomes brown, and is gradually converted into *fuscin.* It is but little soluble in water, but very soluble in alcohol and ether.

Its salts are all oily; and, according to Unverdorben, they resemble the salts of odorin very closely in their properties. But they have been very imperfectly examined. The following are the facts stated by Unverdorben, and I am not aware that they have been examined by any other chemist.

* Unverdorben, Poggendorf's Annalen, xi. 67.

† The name is derived from the first syllables of *ol*eum *an*imale, adding to them the termination *in.*

1. When *Perchloride of Iron* is mixed with *muriate of olanin*, a double oily salt is formed, having a deep brown colour soluble in twice its weight of cold water; but requiring four times its weight of hot water to dissolve it. Hence when a saturated cold solution is raised to the boiling temperature, a great deal of the salt is separated, which is again redissolved as the solution cools. This double salt is neither decomposed by boiling nor by acids. It dissolves in oil of cumin, and water can only take it from that solution by long boiling, and in proportion as the oil evaporates.

2. *Corrosive sublimate* and muriate of olanin form an oily colourless double salt. Olanin combines with corrosive sublimate into a subsalt, little soluble in water, and having a yellow colour. It is fusible, and resembles a resin. It requires a thousand times its weight of boiling water to dissolve it, and from this solution it is deposited in a crystalline form. It is not decomposed by boiling, and is insoluble in alcohol.

3. *Chloride of gold* forms with muriate of olanin a neutral double salt, having a deep-brown colour. It is little soluble in cold, but more soluble in hot water, and is very soluble in alcohol and ether. When this salt is long boiled with water, a little of the gold is reduced to the metallic state.

Chloride of gold and olanin form a subsalt resembling a resin. It is hard, brown, insoluble in water, but soluble in alcohol. If we pour muriatic acid into that solution, the salt becomes neutral. But this scarcely happens unless alcohol be present.

4. With *chloride of platinum*, olanin forms a double neutral salt, which has the appearance of tar. It is more soluble in water than the chloride of gold and olanin. It is also very soluble in alcohol, but insoluble in ether.*

* Unverdorben, Poggendorf's Annalen, xi. 70.

CHAPTER V.

OF AMMOLIN. *

THIS substance, like the three preceding, was first obtained and examined by Unverdorben. His process for obtaining it is the following:

Pour dilute sulphuric acid into *unrectified* Dippel's oil, as long as any effervescence is produced. When this is at an end, add as much more sulphuric acid as has been already mixed with the oil; allow the mixture to remain for some hours, agitating it frequently during that time. When the sulphuric acid liquor and the oil have separated from each other, draw off the oil and wash it with water. Add these washings to the sulphuric acid liquor. This acid solution contains supersulphates of *odorin*, *animin*, *olanin*, and also of *ammolin*, saturated with empyreumatic oil dissolved. To get rid of this last oil, let the liquor be boiled for three hours in an open vessel, replacing the water as it evaporates. By this treatment, a portion of the oil is volatilized, and another portion separates under the form of a brown resin. Mix the liquor, which has now become brown, with a fortieth part of its weight of nitric acid, and evaporate till only a fourth part of the original quantity remains. Add water till the original bulk of the liquid is restored, and after having nearly, but not fully, saturated it with carbonate of soda, distil till what comes over has neither the smell of odorin nor animin. What remains in the retort is a mixture of sulphate of ammonia and sulphate of ammolin. After taking this residue out of the retort, let the sulphuric acid be completely saturated with carbonate of soda, and then evaporate the liquid. Carbonate of ammonia is disengaged, and a brown oil separates. This oil is to be cautiously distilled. What passes over is ammolin, containing an empyreumatic oil, having the smell of horse-radish. What remains in the retort is *fuscin*.

Boil what has been distilled over with water. A portion of the empyreumatic oil is volatilized, and another portion dissolves in the water. The ammolin which remains is a colourless oily body, which is heavier than water, and which instantly restores the colour of litmus-paper reddened by an acid.

* The word is made up of the first syllables of the words *ammoniacum* and *oleum*, adding the termination *in*.

It is so little volatile that when boiled with water very little of it, if any, is volatilized. It dissolves in forty times its weight of boiling water, and 200 times its weight of cold water. If we evaporate the solution, the water may be driven off, leaving the ammolin behind. Ammolin is very soluble in alcohol and ether.

Chlorine decomposes it; the products are muriate of ammolin, animin, fuscin, and an extractive-looking matter. Ammolin combines readily with extractive matter and resins. It is more strongly alkaline than any of the three preceding bases. When boiled with ammoniacal salts, it expels the ammonia, doubtless in consequence of its little volatility. When even a great excess of ammonia is added to an ammolin salt, very little of the ammolin is disengaged.

The ammolin salts are oily, very soluble in water and alcohol; but insoluble in ether. Sulphate and nitrate of ammolin are probably decomposed when distilled, free ammolin coming over, mixed with the products of decomposition. Acetate and muriate of ammolin may be distilled over almost completely, without being decomposed. With succinic and benzoic acids ammolin forms oily salts, which may be heated without undergoing decomposition.*

CHAPTER VI.

OF FUSCIN.†

To Unverdorben we are indebted also for the discovery of *fuscin,* which he extracted from unrectified Dippel's oil by the following process:

One part of the oil is mixed with one-eighth of hydrate of potash dissolved in six parts of water. This mixture is cautiously distilled till the volatile substances and the empyreumatic oil pass into the receiver, and there remains in the retort solution of potash united to pyrozoic acid, on which swims a viscid pitchy substance. It is this last substance which contains the fuscin. When it is digested in acetic acid a portion is dissolved. This portion is precipitated by the alkalies. The precipitate is brown.

* Unverdorben, Poggendorf's Annalen, xi. 74.

† The name derived from, *fuscus, brown.*

Digest it in absolute alcohol, a portion is dissolved. This portion is fuscin. When the alcohol is evaporated, we obtain the fuscin in a brown coloured mass, cracked in all its dimensions.

Fuscin is solid, has a brown colour, and is insoluble in water. The acids dissolve it, and when the solutions are evaporated a brown matter remains, which is soluble in water and in aqueous alcohol ; and which, while in a solid state, may be exposed to the atmosphere without undergoing any alterations. The compounds of fuscin with succinic and benzoic acids constitute an exception to this solubility in water; for they are insoluble in that liquid. When any of the solution of salts of fuscin is mixed with potash, fuscin precipitates, which, when washed and dried, has the form of a brown powder. It does not melt when heated, but is charred, and gives out a smell similar to that of burning horn.

Fuscin, whether in the state of a dry powder, or in solution, in acids gradually absorbs oxygen from the atmosphere, and assumes a red colour. The solutions in that case contain the same substance which alcohol leaves undissolved when digested on the brown matter precipitated by alkalies from the acetic acid solutions mentioned in the process for procuring fuscin. This substance, as well as fuscin, combines with the acids. But it soon loses this property, and assumes the form of a brown powder, insoluble in all menstrua.*

CHAPTER VII.

OF CRYSTALLIN.†

THIS substance was obtained by Unverdorben from indigo; but its analogy to the five preceding bases is so strong, that it was deemed better to place it here than among the products of vegetable substances.

When indigo is distilled *per se* it gives first water and oil, and then oil holding resin in solution passes over. The oil is colourless and volatile, and has not an empyreumatic smell, but one similar to that of indigo when strongly heated. This oil, when left exposed to the air, becomes yellow, and then con-

* Unverdorben, Poggendorf's Annalen, viii. 261.

† So called because its salts are capable of crystallizing, which is not the case with those of any of the preceding five bases.

tains ammonia, crystallin, and several other substances. The crystallin may be obtained by the following process:—

Mix the oil with sulphuric acid, which dissolves it, leaving the other substances behind. Mix the acid liquid with another base, and distil. The *crystallin* passes over.

Crystallin is a colourless oil, which is heavier than water. Its odour is strong, and has some resemblance to that of new honey. It does not react sensibly as an alkali. It is but little soluble in water, yet it may be distilled over with that liquid. When exposed to the air it becomes red, and then communicates a yellow colour to water when dissolved in it.

Sulphate of crystallin crystallizes, whether it be neutral or contain an excess of acid. When the neutral salt is evaporated, it is converted into a supersalt. It is insoluble in absolute alcohol. Its aqueous solution becomes gradually brown, and then it contains sulphate of fuscin. When supersulphate of crystallin is heated, it melts and concretes on cooling into a crystalline mass. When exposed to a stronger heat it undergoes decomposition, and there are formed sulphate of crystallin, sulphate of odorin, and a great quantity of sulphate of ammonia. The charcoal remaining leaves no residue when burnt.

Phosphate of crystallin crystallizes readily, when it is neutral; but the superphosphate does not crystallize at all. Alcohol separates the crystals by removing the excess of acid and the water.*

CHAPTER VIII.*

OF APOSEPEDIN. †

This substance was first noticed by M. Proust in 1818, ‡ who gave it the name of *cheesy oxide.* It was again examined, and its properties ascertained by Braconnot in 1827, § who distinguished it by the name of *aposepedin,* because it is formed when *casein* undergoes a species of putrefaction.

Cheese, as every body knows, consists essentially of coagulated *casein,* ‖ from which the great quantity of liquid which it ori-

* Unverdorben, Poggendorf's Annalen, viii. 397.

† From. ἀπὸ and σηπεδὼν, *putridity.*

‡ Ann. de Chim. et de Phys. x. 40. § Ibid., xxxvi. 161.

‖ This substance will be described in a subsequent chapter of this volume.

ginally contained has been expelled by pressure. When thus treated it may be kept a considerable time, during which it is slowly undergoing an alteration, which renders it more agreeable to the taste. If the liquid portion has not been squeezed out with care, it undergoes a species of putrefaction, similar to what takes place when moist gluten of wheat is left in a similar state. Proust conceived that during this process a peculiar acid was formed, which he distinguished by the name of *caseic acid,* together with another substance which he called *caseous* or *cheesy oxide.* Braconnot showed that the caseic acid of Proust was composed of a congeries of substances which he separated from each other. The cheesy oxide he found a peculiar substance, and distinguished it, as has been already stated, by the name of *aposepedin.*

He mixed 4167 grains of fresh cheese from creamed milk with 61 cubic inches of water, and left the mixture to putrefy for a month in a temperature varying from 68° to 77°. During this interval the greatest part of the cheese was dissolved. The solution was separated by filtrations from the undissolved portions. Its smell was putrid, but no odour of sulphur could be distinguished in it. When evaporated to the consistence of honey it gradually congealed into a granular mass, one portion of which dissolved in alcohol, while another portion remained unattached by that liquid. The first of these portions was the *caseate of ammonia* of Proust, and the second his *caseous oxide.*

This last substance was dissolved in water and the solution treated with animal charcoal, which rendered it colourless. This liquid being left to spontaneous evaporation, deposited brilliant crystalline vegetations, constituting rings and cauliflower-looking concretions on the edges of the liquid. To obtain it perfectly white it was necessary to dissolve and evaporate it two or three times successively. Thus purified its properties were as follows:

Its colour is white; it has no smell, its taste slightly bitter with a flavour of roasted meat. It crackles under the teeth; it is heavier than water, and is easily reduced to powder. It burns away without leaving any residue. When heated in a tube of glass open at both ends a portion of it is volatilized unaltered, under the form of long slender crystals. Every time that this process is repeated a new portion is decomposed. When distilled *per se* in a retort it does not sublime but undergoes decomposition. A solid oil passes over into the receiver together with

a liquid holding carbonate and sulphohydrate of ammonia in solution.

When aposepedin is heated on polished silver, the metal is blackened, being converted into sulphuret. At the temperature of 57° aposepedin is soluble in 22 times its weight of water. The solution speedily putrefies, and acquires a very disagreeable smell.

Aposepedin is very soluble in alcohol. When a boiling alcoholic solution cools, the oxide is precipitated under the form of a fine light powder, which after being dried, has a good deal of resemblance to magnesia. Nitric acid converts it into a bitter matter and a yellow oil; but no oxalic acid is formed. Muriatic acid dissolves a greater quantity of it than water; and when the solution is concentrated, it concretes into a mass on cooling.

The aqueous solution of aposepedin is neither precipitated by alum nor persulphate of iron. The infusion of nut-galls throws it down abundantly in flocks, which are redissolved by adding a great excess of the reagent. When mixed with a solution of sugar no fermentation is produced.

The portion of the cheese dissolved in ammonia owes its acid properties to acetate of ammonia, generated during the putrefaction of the cheese. It contained also a brown extractive matter, ammonia-phosphate of soda and a brown oil, heavier than water, and having an acrid and burning taste. Braconnot considered it as a compound of oleic acid with an acrid oil.

CHAPTER IX.

OF TAURIN.

THIS substance was discovered by L. Gmelin in 1824, during the researches of Tiedemann and Gmelin on ox bile; and its properties were described by him in 1827.* They distinguished it by the name of *gallenasparagin*, which L. Gmelin afterwards changed into *taurin*, obviously from the Latin name of the animal from whose bile it was extracted. There can be little doubt that it was formed from the choleic acid of bile by the processes to which Gmelin subjected ox bile; though he was of opinion that it constituted one of the many ingredients of which he con-

* Poggendorf's Annalen, viii. 326.

sidered the bile to be composed. Gmelin's method of obtaining it was the following:

Ox bile was mixed with muriatic acid, and filtered to separate a mucous or albuminous matter which had precipitated; the filtered liquor being left for some days in repose, some stearic acid was deposited. The filtered liquor was then concentrated by evaporation till only a small quantity remained. This residue consisted of a resinous matter and an acid liquor. The liquor being separated from the resin and still farther concentrated, more of the resin fell, and finally crystals of *taurin* and of common salt were deposited. The taurin was picked out and purified by a second crystallization. When the resin is dissolved in absolute alcohol and the solution filtered, taurin in small crystals remains on the filter. It may be purified by washing it in absolute alcohol, dissolving it in water and crystallizing.

Thus purified taurin consists of transparent colourless crystals. The primitive form is a right rhombic prism with angles of 111° 44′, and 68° 16′. But it is usually in six or eight-sided prisms, terminated by four or six-sided pyramids. These crystals crackle under the teeth, and have a sharp taste, neither sweetish nor saline. Taurin neither reacts as an acid nor an alkali, and is not altered by exposure to the air, even when heated to 212.° When strongly heated taurin melts into a thick liquid, becomes brown, swells, and exhales an agreeable but empyreumatic odour, similar to that of burning indigo. It leaves a charcoal which is easily consumed. When distilled *per se* it gives a thick brown oil with a little yellow coloured and acidulous water, which contains an ammoniacal salt in solution, and reddens a solution of perchloride of iron.

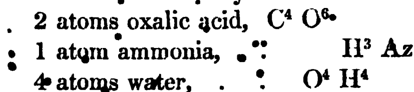
Taurin dissolves in 15½ times its weight of water at the temperature of 54.° It is much more soluble in boiling water, and the surplus crystallizes as the solution cools. Boiling alcohol of 0·835 dissolves only $\frac{1}{573}$th part of its weight of taurin, and in absolute alcohol it is almost insoluble.

Concentrated sulphuric acid dissolves it without the assistance of heat, forming a transparent brown liquor from which the taurin is not precipitated by water. When this solution is raised to the boiling point its colour becomes darker, but no sulphurous acid is disengaged. Cold nitric acid dissolves taurin readily, and when the acid is evaporated away the taurin remains unaltered.

The aqueous solution of taurin is not sensibly acted on by muriatic acid, potash, ammonia, alum, chloride of tin, chloride

of iron, sulphate of copper, corrosive sublimate, nitrate of mercury, or by nitrate of silver.

Taurin, according to the analysis of M. Demarçay, is composed of $C^4\ H^7\ Az\ O^{10}$. This may be resolved into,



2 atoms oxalic acid, $C^4\ O^6$
1 atom ammonia, $H^3\ Az$
4 atoms water, $O^4\ H^4$

$C^4\ H^7\ Az\ O^{10} = 15{\cdot}625$

This composition has been confirmed by the analysis of Dumas and Pelouse.*

CHAPTER X.

OF CHITIN.

THIS name (from χιτων, *tunica*) has been given by Dr Odier to the hard horny crust which forms the outer covering of many insects, and in particular the elytra of the coleopterous insects.† When these elytra are boiled in a solution of caustic potash, the menstruum extracts albumen, a matter analogous to the *extract* of meat, and a fatty coloured matter which is soluble in the alkali; but insoluble in alcohol and water. What remains is *chitin.*

Chitin is white and translucent. It does not melt when heated; but is charred without giving out ammonia or hydrocyanic acid. It is soluble in dilute sulphuric acid, and in nitric acid when assisted by heat. The solution in nitric acid is not yellow.

CHAPTER XI.

OF AMMONIA.

AMMONIA is beyond question the most important of all the animal bases. But its use is so indispensable to the chemist at the very commencement of his investigations, that it it was necessary to describe its properties while treating of the Chemistry of Inorganic Bodies. (Vol. i. p. 138.)

* Ann. der Pharm xxvii. 292.
† Odier, Mem. de Mus. d'Hist. Nat. i. 35.

It enters into a greater number of combinations than perhaps any other base whatever. I propose in this section to give merely a catalogue of the most important of these compounds, and, at the same time, to explain the views at present entertained respecting their nature.

Ammonia has been long known to be a compound of azote and hydrogen. But azote and hydrogen are at present conceived to be capable of uniting in three different proportions.

1. The first, called *amide*, is a compound of one atom azote, and two atoms hydrogen, $Az\ H^2 = 2$. It is considered as the radical of ammonia, and has not hitherto been obtained in an isolated form. It is not a base; but is capable of combining with bases, and seven of such compounds are known.

2. The second compound of azote and hydrogen is *ammonia*. It consists of one atom of azote combined with three atoms ammonia, $Az\ H^3 = 2{\cdot}125$. It is a powerful base, and readily combines with and neutralizes acids.

3. The third compound of azote and hydrogen is called *ammonium*. It is a compound of one atom of azote with four atoms hydrogen, $Az\ H^4 = 2{\cdot}25$. It possesses the character of a metal, and is capable of combining with metals. Hitherto it has not been obtained in an isolated state. But all the ammoniacal salts containing oxygen acids are considered at present as compounds of the acid and oxide of ammonium.

Let us take a view of the compounds which these three modifications of ammonia are capable of forming.

I. AMIDES.

1. Amide of potassium, . $Az\ H^2 + K = 7$
2. Amide of sodium . $Az\ H^2 + Na = 5$
3. Amide of mercury, . $Az\ H^2 + Hg = 14{\cdot}5$

White precipitate, $Az\ H^2\ Hg + Chl.\ Hg = 31{\cdot}5$ (Kane) obtained by precipitating corrosive sublimate by caustic ammonia.

When white precipitate is treated with caustic potash, we obtain a yellow powder composed of $Az\ H^2\ Hg + 2\ Hg\ O + Chl.\ Hg = 58{\cdot}5$ (Kane.)

A number of other complex compounds have been analysed by Dr Kane of Dublin.

4. Amide of copper and hyposulphate of ammonium, $Az\ H^2\ Cu + (S^2\ O^5)\ (Az\ H^4\ O) = 18{\cdot}25$.

5. Amide of copper and nitrate of ammonium, $Az\ H^2\ Cu + (Az\ O^5) + (Az\ H^4\ O) = 16$.

And so of the other compounds of metallic amides with salts of ammonium.

1. Oxamide, $C^2\ O^2 + Az\ H^2 = 5{\cdot}5$.

This was the substance originally discovered by Dumas, which led to the whole doctrine of amides. It is oxalate of ammonia — an atom of water

2. Sulphamide, $Az\ H^2 + SO^2 = 6$.

Discovered by Regnault. Obtained by mixing chlorine gas, sulphurous acid gas and olefiant gas. A liquid is formed which, by a current of ammoniacal gas, is converted into a white powder and sal-ammoniac. The white powder is sulphamide.

3. Sulphohydramide, $SO^3 + Az\ H^4 = 7{\cdot}25$.

The anhydrous sulphate of ammonia of Rose.

4. Bisulphohydramide, $2\ (S\ O^2) + Az\ H^4 = 10{\cdot}25$.

The anhydrous acid sulphite of ammonia discovered by Rose.

II. AMMONIA, $Az\ H^3 = 2{\cdot}125$.

1. Liquid ammonia, $Az\ H^3 + 3\ Aq$.

It dissolves oxides of zinc, copper, nickel, cobalt, &c.

2. Ammoniated oxide of copper, $2\ (Az\ H^3) + 3\ (Ca\ O) + 6\ Aq = 26$ (Kane.)

A blue powder.

3. Ammoniated oxide of mercury, $Az\ H^3 + 3\ (Hg\ O) + 3\ Aq = 46$ (Kane.)

And so of the other ammoniated oxides.

1. Ammonietted chloride of sulphur, $Az\ H^3 + S\ Chl = 8{\cdot}625$ and $2\ (Az\ H^3) + S\ Chl = 10{\cdot}75$.
2. Ammonietted sesquichloride of phosphorus, $5\ (Az\ H^3) + (Ph\ Chl^{1\frac{1}{2}}) = 21{\cdot}375$.
3. Ammonietted perchloride of phosphorus, $5\ (Az\ H^3) + Ph\ Chl^{2\frac{1}{2}} = 23{\cdot}875$.
4. Ammonietted chloride of boron, $3\ (Az\ H^3) + 2\ (Bo\ Chl^{1\frac{1}{2}}) = 15{\cdot}125$.
5. Ammonietted perchloride of tin, $Az\ H^3 + 2\ (St\ Chl^2) = 18{\cdot}375$.
6. Ammonietted chloride of calcium, $4\ (Az\ H^3) + Ca\ Chl = 15{\cdot}5$.
7. Ammonietted chloride of strontium, $4\ (Az\ H^3) + Str\ Chl = 18{\cdot}5$.

8. Ammonietted chloride of copper, 3 (Az H^3) + Cu Chl = 14·875.
9. Ammonietted chloride of nickel, 3 (Az H^3) + N Chl = 14·125.
10. Ammonietted chloride of cobalt, 2 (Az H^3) + Cb Chl = 12.
11. Ammonietted chloride of lead, 3 (Az H^3) + 4 (Pb Chl) = 76·375.
12. Ammonietted chloride of antimony, Az H^3 + Sb $Chl^{3\frac{1}{2}}$ = 21·375.
13. Ammonietted chloride of mercury, Az H^3 + 2 (Hg Chl) = 36·125.
14. Ammonietted dichloride of mercury, Az H^3 + 2 (Hg^2 Chl) = 61·125.
15. Ammonietted chloride of silver, 3 (Az H^3) + 2 (Ag Chl) = 42·375.
16. Ammonietted chloride of platinum, Az H^3 + Pl Chl = 18·625.

Ammonia combines also with bromides, iodides, and fluorides. It combines also with sulphates of magnesia, zinc, copper, nickel, cobalt, cadmium, silver, and with nitrate of silver; though the exact proportions have not been determined.

III. AMMONIUM, Az H^4 = 2·25

Amalgam of ammonium, Hg + Az H^4 = 14·75.

1. Sal-ammoniac, or chloride of ammonium, Chl + Az H^4 = 6·75.
2. Chloride of ammonium and magnesium, (Chl + Az H^4) + Mg Chl = 12·75.
3. Chloride of ammonium and zinc, 2 (Chl + Az H^4) + 2 (Zn Chl) + Aq = 31·875, (Kane.)

There is another compound constituting a pearly powder, which contains also oxide of zinc, according to the analysis of Kane.

4. Chloride of ammonium and nickel, (Chl + Az H^4) + (Az H^3 + N O) + Aq = 14·25.
5. Chloride of ammonium and copper, (Chl + Az H^4) + Cu Chl + Aq = 16·375.
6. Chloride of ammonium and mercury, (Chl + Az H^4) + Hg Chl + Aq = 24·875.
7. Chloride of ammonium and platinum, (Chl + Az H^4) + Pl Chl = 23·25.
8. Bromide of ammonium, Az H^4 + Br = 12·25.

9. Iodide of ammonium, $Az H^4 + I = 17 \cdot 875$.
   Iodide of ammonium and gold, $(I + Az H^4) + Au I^3 = 77 \cdot 626$.
10. Fluoride of ammonium, $Az H^4 + Fl = 4 \cdot 5$.
11. Seleniet of ammonium, $Az H^4 + Se = 7 \cdot 25$.
12. Sulphuret of ammonium, $Az H^4 S = 4 \cdot 25$.
13. Bisulphuret of ammonium, $Az H^4 S^2 = 6 \cdot 25$.
14. Persulphuret of ammonium, $Az H^4 S^5 = 12 \cdot 25$.
   Sulphohydrate of ammonium, $Az H^4 S + HS = 6 \cdot 375$.
   Bisulphocarburet of ammonium, $Az H^4 S + CS^2 = 9$.
15. Oxide of ammonium, $Az H^4 O = 3 \cdot 25$.
16. Sulphate of ammonium, $SO^3 + Az H^4 O + Aq = 9 \cdot 375$.
17. Bisulphate of ammonium, $2 (SO^3) + Az H^4 O = 13 \cdot 25$.
18. Ammonium-sulphate of magnesia, $(SO^3 + Az H^4 O) + (SO^3 + Mg O) + 7 Aq = 23 \cdot 625$.
19. Ammoniacal alum, $(SO^3 + Az H^4 O) + 3 (SO^3 + Al O) + 24 Aq = 54$.

And so with the double ammoniacal salts described in the Chemistry of Inorganic Bodies, (Vol. ii. p. 750.) Adding an atom of water to convert ammonia into oxide of ammonium.

1. Nitrate of ammonium, $Az O^5 + Az H^4 O = 10$.
   And so with the double ammoniacal nitrates.
2. Chlorate of ammonium, $Chl O^5 + Az H^4 O = 12 \cdot 75$.
3. Iodate of ammonium, $IO^5 + Az H^4 O = 24$.
4. Carbonate of ammonium, $CO^2 + Az H^4 O = 6$. This salt exists only in solution.
   And so with the double ammoniacal carbonates.
5. Phosphate of ammonium, $2 (PO^{2\frac{1}{2}}) + Az H^4 O + 2 (H O) + Aq = 15 \cdot 625$, and $2 (PO^{2\frac{1}{2}}) + 2 (Az H^4 O) + H O = 16 \cdot 625$.
6. Soda-phosphate of ammonium, $2 (PO^{2\frac{1}{2}}) + \left\{\begin{matrix} Na O \\ Az H^4 O \\ H O \end{matrix}\right\} + 8 Aq = 26 \cdot 375$.
   And so with the other double ammoniacal phosphates.
7. Chromate of ammonium, $Chr O^3 + Az H^4 O + Aq = 10 \cdot 875$.
8. Permanganate of ammonium, $Mn O^7 + Az H^4 O + Aq = 14 \cdot 875$.
9. Tungstate of ammonium, $Tu O^3 + Az H^4 O + Aq = 19 \cdot 875$.

10. Molybdate of ammonium, $Ml\ O^3 + Az\ H^4\ O = 12{\cdot}25$.
11. Vanadiate of ammonium, $VO^3 + Az\ H^4\ O = 14{\cdot}75$.
12. Selenite of ammonium, $Se\ O^2 + Az\ H^4\ O = 10{\cdot}25$.

For farther information respecting the compounds of ammonia, we refer the reader to the Memoir of M. Bineau in the Annal. de Chim. et de Phys. lxvii. 225; and Ibid. lxx. 251.

CLASS III.

INTERMEDIATE ANIMAL OXIDES.

THE animal principles belonging to this class have been so imperfectly examined, that the characters of many of them are only inferred from very imperfect analogies. We shall divide them into five sets.

1. Oxides containing azote and not oily.
2. Oxides not containing azote and not oily.
3. Oily oxides saponifiable.
4. Oily oxides not saponifiable.
5. Colouring matters.

It can scarcely be doubted that the oily saponifiable oxides contain an acid; and it is probable that the animal colouring matters resemble the vegetable in their nature.

CHAPTER I.

OF ANIMAL OXIDES CONTAINING AZOTE AND NOT OILY.

THESE bodies have been all recently discovered, and most of them have been formed artificially by treating uric acid with various reagents. They are eight in number; namely,

1. Xanthic or uric oxide.
2. Cystin.
3. Allantoin.
4. Alloxane or erythric acid.
5. Alloxantine.
6. Uramile.
7. Murexide.
8. Murexane.

SECTION I.—OF XANTHIC OR URIC OXIDE.

Dr Marcet gave the name of *xanthic oxide* to the constituent portion of a small calculus, which Dr Babington having received from one of his patients gave to Marcet for examination. Its texture was compact, hard, and laminated. The surface was smooth, and it had a reddish cinnamon colour, which was much heightened by adding caustic alkali to the calculus in powder. Before the blow-pipe, it crackled, split in pieces, became black, and was ultimately consumed, leaving only a minute particle of white ash. The smell which it emitted was that of an animal substance, and was peculiar, though feeble and not easily defined.

When exposed to destructive distillation, it crackled, split into scaly fragments, blackened, and emitted a fetid ammoniacal liquor, from which carbonate of ammonia crystallized, leaving a heavy yellowish oil.

When reduced to an impalpable powder, the greatest part of it dissolved in boiling water, and the solution reddened litmus paper. When the liquid was allowed to cool, it became covered with a white flocculent film, which gradually subsided and constituted a white crust.

Caustic potash dissolved this calculus very readily, and the solution was precipitated by acetic acid, provided the acid was not added in great excess. The mineral acids also dissolved it, though not nearly so readily as the alkalies. Concentrated sulphuric acid did not blacken it.

When the solution of the calculus in nitric acid was evaporated to dryness, the residue assumed a bright lemon colour. This yellow residue was partly soluble in water, to which it communicated its colour. The addition of an acid destroyed the yellow colour, but caustic potash turned it red, and upon evaporation, it assumed a brilliant crimson hue. This colour disappeared on adding water, the yellow tint being reproduced, while the liquid remained transparent. The previous action of nitric acid is necessary for these changes of colour: for if potash be added to the pure xanthic oxide, no change of colour takes place.

Xanthic oxide is insoluble in alcohol and ether, very sparingly soluble in acetic, and not at all in oxalic acid. It is insoluble in bicarbonate of potash and bicarbonate of ammonia.*

Such are the properties of this uncommon substance as deter-

* Marcet's Essay on Calculous Disorders, p. 96.

mined by Dr Marcet. In the year 1819, a similar calculus was extracted from a patient by Langenbeck, and given to Stromeyer, who determined it to be the same as the xanthic oxide of Marcet. A considerable portion of this calculus is still in Langenbeck's collection. It weighs eleven grammes, or almost 170 grains. It is much largor than the one described by Marcet. It has been lately examined and analyzed by Wöhler and Liebig. *

The surface of the calculus was partly light brown, smooth, and shining, partly earthy and whitish. The fracture had a brownish flesh-colour. It was composed of concentric layers, separable from each other, and had a nucleus composed of the same matter with the rest of the calculus. It had the same degree of hardness as the uric acid calculi. When rubbed or scraped, it assumed a waxy lustre.

As it might be supposed to contain more or fewer of the constituents of urine, Wöhler and Liebig purified the *xanthic* oxide, or *uric oxide*, as they have called it, in the following way:—The calculus was pulverized and dissolved in caustic potash. The solution had a dark brownish yellow colour, with a shade of green, not unlike the colour of bile. Through this solution pure carbonic acid gas was passed till the potash was converted into bicarbonate. The *uric oxide* precipitated in the form of a white powder. When this powder was washed and dried, it assumed the form of masses of a light yellow, which, when rubbed, acquired a waxy lustre. It contained no trace of potash, differing in this respect from uric acid. For when an alkaline solution of this last is saturated with carbonic acid gas, the precipitate is not pure uric acid, but urate of potash.

Uric oxide is soluble in sulphuric acid, and the solution has a yellow colour. The oxide is not precipitated by water. In this respect also it differs from uric acid It is insoluble in muriatic and oxalic acid; a circumstance which distinguishes it from cystic oxide.

When subjected to destructive distillation it so far resembles uric acid, that a great deal of hydrocyanic acid is evolved. But the empyreuma has a different smell, similar to that of distilled horn. There is given out also a sublimate of carbonate of ammonia, but no urea.

When heated with oxide of copper the azotic was to the car-

* Ann. der Pharm. xxvi. 340.

bonic acid gas as 1 : 2·5. The result of an analysis of this substance in Liebig's laboratory gave its composition

Carbon,	39·28 or 5 atoms	= 3·75	or per cent.	39·48
Hydrogen,	2·95 or 2 atoms	= 0·25	...	2·63
Azote,	36·35 or 2 atoms	= 3·5	...	36.84
Oxygen,	21·42 or 2 atoms	= 2·	...	21·05
	100.00 *	9·5		100·

So that its formula is $C^5 H^2 Az^2 O^2 = 9·5$. We have seen before that the formula for uric acid is $C^{10} H^4 Az^4 O^6$. Now the half of this is $C^5 H^2 Az^2 O^3$. So that uric oxide differs from uric acid by containing one atom less oxygen. It may probably be at least occasionally an ingredient in urine; though it is so very seldom deposited in a solid form.

SECTION II.—OF CYSTIN.

This name has been applied to the substances constituting the whole, or almost the whole of the calculus first observed and described by Dr Wollaston, and called by him *cystic oxide*. † This calculus Dr Wollaston had obtained about the year 1805 from Dr Reeve of Norwich. It had been taken from his brother, when he was five years old, and at that time was covered by a coating of phosphate of lime very loose in its texture, and consequently very soon separated. Dr Wollaston only met with one other calculus of the same kind. It was in the collection of calculi in Guy's Hospital, and was No. 46 of that collection. It was extracted by the usual operation from William Small, a man of 36 years of age. Dr Henry of Manchester afterwards found two calculi in his collection belonging to the same species; and Dr Marcet detected cystic oxide calculus in no fewer than three different cases, of which he has given a description.‡ Some years ago I was kindly presented with another calculus belonging to the same species by Dr Apjohn, which had been extracted by the usual operation in Dublin. M. Lassaigne, in 1823, announced that he had found the same substance in a calculus from a dog.§

* There must be a typographical error in the data from which this composition was deduced. For when we calculate from them the result differs enormously from the statement in the text, deduced by Liebig from his analysis.

† Phil. Trans. 1810, p. 223.

‡ *On the Chemical History and Medical Treatment of Calculous Disorders*, p. 28.

§ Ann. de Chim. et de Phys. xxiii. 328.

But his analysis differs so much from that of cystic oxide by Dr Prout, that I consider it impossible that both operated upon the same substances. Two cystic oxide calculi exist also in the Museum of St Bartholomew, and have been described by Mr Taylor.* One of them weighed 740 grains. It is, therefore, the largest calculus of this species hitherto observed. It was analyzed by Mr Taylor, and found composed of,

Cystic oxide,	91
Phosphate of lime,	3·8
Ammonia-phosphate of magnesia,	1·0
Animal matter,	4·2
	100·0

About the year 1836, M. O. Henrie got two very small calculi of the same species, which had been passed with great pain by an individual 50 years of age. †

Cystic oxide calculi have a pale yellow colour, are translucent, and appear irregularly crystallized. They are not composed of distinct laminæ, but constitute one compact mass. They have also a peculiar glistening lustre, like that of a body having a high refractive density.

When cystic oxide is submitted to destructive distillation, it yields fœtid carbonate of ammonia, partly fluid, and partly in a solid state, a heavy fœtid oil, and there remains a black spongy coal, much smaller in proportion than is found after the distillation of uric acid calculi.

Under the blowpipe it may be distinguished by the smell, which at no period resembles that of hydrocyanic acid; but, in addition to the usual smell of burnt animal substances, there is a peculiar fœtor quite different from that of any other substance.

Cystic oxide is not soluble in water, alcohol, acetic acid, tartaric acid, citric acid, nor in bicarbonate of ammonia. It is dissolved in considerable quantity by muriatic, nitric, sulphuric, phosphoric, and oxalic acids. It is also dissolved readily by pure alkaline menstrua, by potash, soda, ammonia, and lime-water. Even bicarbonates of potash and soda dissolve it.

The combination of cystic oxide with acids may be made to crystallize without difficulty, and they form slender spiculæ radiating from a centre, which readily dissolve again in water, un-

* Phil. Mag. (3d series) xii. 237. † Jour. de Pharm., xxiii. 71.

less they have been injured by having been in any degree overheated. The muriatic salt is decomposed at 212°, in consequence of the volatility of its acid, and the rest are easily destroyed by a greater excess of heat.

The salt formed by combination with nitric acid does not yield oxalic acid, and does not become red when similarly treated with uric acid; but assumes a brown colour, becoming gradually darker till it is ultimately black.

When the combinations with alkalies are evaporated they leave small granular crystals. The only definite form observed was that of flat hexagonal plates. But the primary shape of the crystal could not be ascertained. On the cystic oxide calculus in Guy's Hospital minute crystals nearly cubical were observed; but whether these were crystals of cystic oxide was not determined.

Dr Prout subjected cystic oxide to an ultimate analysis, and obtained,

Carbon,	29·875	or 6 atoms	= 4·5	or per cent. 30
Hydrogen,	5·125	or 6 atoms	= 0.75	5
Azote,	11·85	or 1 atom	= 1·75	11·67
Oxygen,	53·150	or 8 atoms	= 8·00	53·33
	100·00		15·	100·

These numbers merely express the smallest ratios of the number of atoms of each constituent which cystin contains. For no experiments have been made to determine its atomic weight. The analogy of uric oxide and urea would lead us to double the number of atoms of each constituent, and to represent the constitution of cystin by the following formula, $C^{12} H^{12} Az^{2} O^{16} = 30$.

SECTION III.—OF ALLANTOIN.

This substance was first detected by Vauquelin and Buniva in the liquor of the amnios of the cow, and was called by them *amniotic acid.** It was afterwards found that the liquor from which it was extracted was not that contained in the amnios but in the *allantois.* This induced chemists to change its name to *allantoic acid;* and Wöhler and Liebig having found it incapable of neutralizing alkaline bases changed that name to allantoin.

An account has been given in the Chemistry of Vegetable Bodies, (p. 212) of the method employed by Wöhler and Liebig

* Ann. de Chim. xxxiii. 279.

to form allantoin artificially. But it will be requisite in this place to be somewhat more particular.

Pure uric acid extracted from the excrements of serpents was mixed with water* to the consistence of a thin pap. This mixture was raised to the boiling point, and peroxide of lead in fine powder was added by little and little. A reaction took place, carbonic acid was given out with effervescence. The pap thickened considerably unless water was added; and the peroxide of lead disappeared. More and more of this peroxide was cautiously added, taking care to renew the water and to keep the whole in a boiling heat till the mixture, by assuming a chocolate colour, indicated that a slight excess of peroxide had been added. The whole was then filtered while hot, and the matter on the filter was repeatedly washed with boiling water.

The filtered liquid was colourless, and on cooling deposited a great number of hard brilliant crystals, which were colourless, or had only a very slight tint of yellow. These crystals constitute *allantoin*. The mother water by evaporation yields an additional quantity of them.

The liquid, after depositing the allantoin, having been evaporated to the consistence of a syrup over the water-bath, yielded on cooling long prismatic crystals of *urea*. The white matter collected on the filter is oxalate of lead. If we wash it, mix it with water, and pass through it a current of sulphuretted hydrogen, the oxalic acid freed from lead dissolves in the water, and may be obtained in crystals.

Thus the products of the reaction of uric acid and peroxide of lead are *allantoin*, *urea*, *oxalic acid*, *carbonic acid*, and *protoxide of lead*, and these are the only products.

Wöhler and Liebig compared the allantoin thus obtained with a quantity of allantoin from the liquor of the allantois of a calf which they had in their possession, and found the two to agree in their characters and composition.

The crystals are colourless and transparent. Their primitive form is a rhomboid. They are hard and their faces are very brilliant. They are tasteless and do not alter the colour of litmus-paper. At 68° allantoin is soluble in 160 times its weight of water. But it is much more soluble in hot water, and crystallizes while the solution is cooling. It does not combine with the

* Ann. de Chim. et de Phys. lxviii. 228.

bases into salts, and therefore is not entitled to be considered as an acid. The oxide of silver makes the only exception to this. Allantoin forms with it a compound, which is a white powder. It may be obtained by mixing aqueous solutions of nitrate of silver and allantoin together, and adding ammonia drop by drop, as long as a precipitate continues to fall. The dilute acids decompose this compound, disengaging the allantoin.

At a high temperature it is decomposed by the caustic alkalies into ammonia and oxalic acid. This decomposition is most easily observed when we employ barytes. If we dissolve allantoin in boiling hot barytes water, ammonia is disengaged and a white powder falls, which is oxalate of barytes. When allantoin is heated with sulphuric acid exactly the same decomposition takes place; only instead of oxalic acid, carbonic acid and carbonic oxide are disengaged, and the ammonia combines with the acid.

Allantoin being subjected to an ultimate analysis in Liebig's laboratory, was found composed of,

Carbon, .	30·20 or 4 atoms	= 3·000	or per cent.	30·38
Hydrogen,	4·04 or 3 atoms	= 0·375	...	3·80
Azote, .	35·27 or 2 atoms	= 3·500	...	35·44
Oxygen, .	30·49 or 3 atoms	= 3·000	...	30·38
	100·00	9·875		100·

We might consider it as a compound of,

2 atoms cyanogen, . $C^4 Az^2$
3 atoms water, . . $H^3 O^3$

To convert it into oxalate of ammonia, or $C^2 O^3 + Az H^3$, we must add three atoms water. We have then,

Allantoin, . $C^4 H^3 Az^2 O^3$
3 atoms water, . $H^3 O^3$

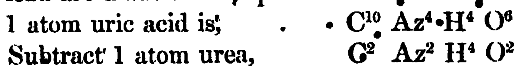
$C^4 H^6 Az^2 O^6$. Now two atoms oxalate of ammonia, $C^4 O^6 + Az^2 H^6$

The compound of allantoin and oxide of silver being analyzed in Liebig's laboratory, was found composed of,

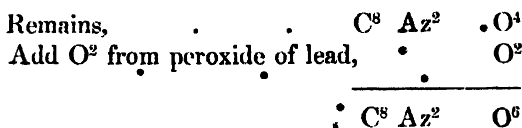
Allantoin, .	56·45 or	18·79
Oxide of silver,	43·55 or	44·5
	100·	

If it consist of 2 atoms allantoin united with one atom oxide of silver, then an atom of allantoin will weigh 9·4, which approaches the number 9·875, resulting from Liebig's formula.

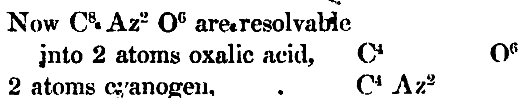
The constitution of allantoin, urea, and oxalic acid being known, it is easy to see what happens when uric acid and peroxide of lead are made to act upon each other.



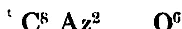
1 atom uric acid is,	$C^{10}\ Az^{4}\ H^{4}\ O^{6}$
Subtract 1 atom urea,	$C^{2}\ Az^{2}\ H^{4}\ O^{2}$



Remains,	$C^{8}\ Az^{2}\ O^{4}$
Add O^{2} from peroxide of lead,	O^{2}
	$C^{8}\ Az^{2}\ O^{6}$



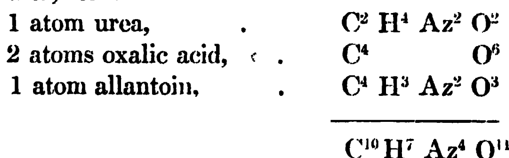
Now $C^{8}\ Az^{2}\ O^{6}$ are resolvable into 2 atoms oxalic acid,	$C^{4}\ O^{6}$
2 atoms cyanogen,	$C^{4}\ Az^{2}$



$C^{8}\ Az^{2}\ O^{6}$

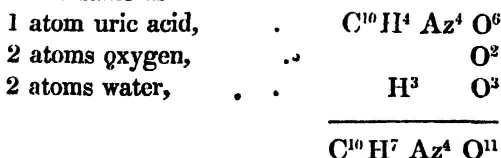
Now we have seen already that if three atoms water be added to 2 atoms cyanogen, we have an atom of allantoin or $C^{4}\ Az^{2}\ H^{3}\ O^{3}$.

Thus we see that 1 atom of uric acid + 2 atoms oxygen + 3 atoms water, form



1 atom urea,	$C^{2}\ H^{4}\ Az^{2}\ O^{2}$
2 atoms oxalic acid,	$C^{4}\ O^{6}$
1 atom allantoin,	$C^{4}\ H^{3}\ Az^{2}\ O^{3}$
	$C^{10}\ H^{7}\ Az^{4}\ O^{11}$

Which is the same as



1 atom uric acid,	$C^{10}\ H^{4}\ Az^{4}\ O^{6}$
2 atoms oxygen,	O^{2}
2 atoms water,	$H^{3}\ O^{3}$
	$C^{10}\ H^{7}\ Az^{4}\ O^{11}$

The carbonic acid evolved is obviously owing to the action of the peroxide of lead on the oxalic acid.

Liebig conceives that the reason why the atomic weight of allantoin in the allantoate of silver is less than that deduced from analysis, is that two atoms of allantoin, when they unite with oxide of silver, lose an atom of water, so that they become $C^{8}\ Az^{4}\ H^{5}\ O^{5}$.

SECTION IV.—OF ALLOXANE OR ERYTHRIC ACID.

This remarkable substance was discovered in 1819 by Dr Gaspard Brugnatelli;* but succeeding experimenters were unable to succeed in forming it till it was discovered again in 1838 by Wöhler and Liebig, who gave a minute detail of the process which they followed.†

The substances formed by the action of nitric acid on uric acid vary with the strength of the nitric acid and the temperature. Alloxane is the compound obtained when the nitric acid is concentrated. If we put into cold nitric acid of the specific gravity 1·425 dry uric acid, a strong effervescence takes place, a good deal of carbonic acid is disengaged together with some nitrous acid, and when the gases cease to be evolved, the liquid assumes the state of a thick bouillée consisting of small prismatic crystals. The mother water contains ammonia. A gentle heat determines the evolution of pure azotic gas. The mass contains nothing but ammonia, and the small crystals, which consist of pure *alloxane*.

If in this experiment we employ a great excess of nitric acid, and if we boil it with the crystals, on allowing the matter to cool, long straight prismatic crystals are formed, having a very strong resemblance to oxalic acid.

If we employ nitric acid of the specific gravity 1·55, alloxane is still formed; but a portion of the uric acid undergoes other modifications. Small masses of it become brown or black as if charred, and the colouring matter which is developed is not easily removed from the crystals.

Wöhler and Liebig employed the following process for preparing alloxane. The most concentrated fuming nitric acid is mixed with the ordinary acid of commerce so as to form a liquid having a specific gravity from 1·45 to 1·5. This mixture is put into a very shallow porcelain evaporating basin, and then is added to it by little and little at a time half its weight of dry uric acid; every portion added being mixed very carefully with the nitric acid. On every addition an effervescence takes place, and care must be taken to wait till the effervescence is over, and the liquid cold, before any more of the uric acid be added.

By this process we obtain a mass almost solid, consisting of brilliant and transparent crystals. It is poured upon a very

* Ann. de Chim. et de Phys. viii. 201. † Ibid. lxviii. 240.

porous brick or upon bloating-paper. In twenty-four hours the liquid portion is removed, and there remains a dry white powder, easily purified by repeated crystallizations. It is mixed with its own weight of water in a porcelain capsule, and heated till complete solution takes place. The solution being filtered and left in a warm place, colourless transparent crystals, having the diamond lustre and considerable bulk, are gradually deposited. These crystals constitute *alloxane* in a state of purity.

Alloxane crystallizes in water under different forms. On allowing a hot saturated solution to cool, very bulky crystals are formed, very deliquescent, and containing a great deal of water of crystallization. The crystals deposited in a hot solution are always anhydrous, and do not effloresce. The form of the crystal is a right prism with a rectangular base, and its primary form is a rhomboid. They have a pearly lustre, especially after having been kept for some time, and may be easily obtained an inch in length. The anhydrous crystals have the form of pyroxen; the primitive form being an oblique prism with a rhomboidal base. The crystals have usually the form of rhomboidal octahedrons truncated on the angles. They have a vitreous lustre, are transparent and much smaller than the hydrous crystals.

Alloxane is soluble in alcohol, and very soluble in water. Its solution communicates a red stain to the skin, and a peculiar disagreeable smell. It reddens litmus-paper; but loses that property when a base is present, although it does not form a salt. Its solution does not decompose the carbonates of lime or barytes. Oxide of lead may be boiled with it, without occasioning any alteration. From these facts, it is obviously not entitled to the name of *acid*.

After the addition of an excess of barytes water, the liquid solution of alloxane remains for some time clear and colourless, but after some hours, it deposites white brilliant crystals, which are soluble in hot water, and again deposited when the solution cools. An excess of lime-water occasions an immediate white crystalline precipitate, soluble in a great quantity of water.

When alloxane is mixed with the salts of protoxide of iron, it occasions at first no precipitate; but the liquid assumes an intense indigo blue colour.

Alloxane, heated with sulphuric acid and metallic copper, does not give out a trace of oxide of azote or of nitrous acid. When

a solution of alloxane is gently heated with peroxide of lead, pure carbonic acid gas is given out. After the process is over, we obtain a white magma of carbonate of lead, containing merely a trade of oxalate. The filtered liquor does not contain any lead; but when evaporated, yields crystals of urea, mixed with a very minute quantity of a white powder. Thus by the action of peroxide of lead, alloxane is decomposed into carbonic acid and urea.

Alloxane was analyzed with much care in Liebig's laboratory. The atoms of carbon were to those of azote as 4 : 1. The mean of five analyses made with oxide of copper gave,

Carbon,	30·22 or	8 atoms =	6	or per cent. 30
Hydrogen,	2·54 or	4 atoms =	0·5	... 2·5
Azote,	17·63 or	2 atoms =	3·5	... 17·5
Oxygen,	49·61 or	10 atoms =	10·0	... 50·0
	100·00		20·0	100.

The theoretic constitution, or $C^8 H^4 Az^2 O^{10}$, corresponds very well with the analysis.

When the crystals of hydrated alloxane are heated, the water which they contain is disengaged, and they are converted into small crystals of anhydrous alloxane. This, as is well-known, is the case when sulphate of zinc is heated. The hydrated crystals effloresce very quickly in a hot place or in a vacuum, become opaque and white, and fall into powder. When deprived of their water by heat, they diminish in weight about 26·3 per cent.—hence they are composed of,

1 atom alloxane,	20	or 74·76
6 atoms water,	6·75	or 25·24
		100.

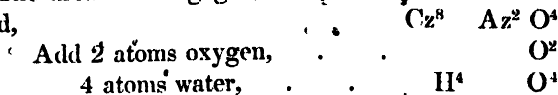
When alloxane is heated, the crystals assume a slight shade of red.

The composition of alloxane being known, it is easy to explain its formation by the action of nitric acid on uric acid.

It has been already stated that uric acid may be considered as a compound of an unknown acid and urea.

1 atom of urea is	$C^2 H^4 Az^2 O^2$
1 atom of the acid,	$C^8 Az^2 O^4$

The urea is disengaged, and there remains the



acid, . . C^8 Az^2 O^4

Add 2 atoms oxygen, . . O^2

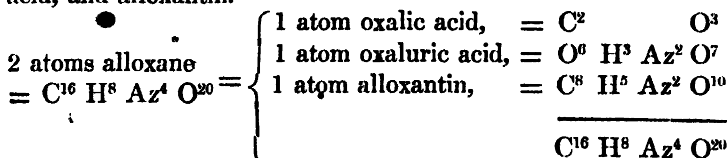
4 atoms water, . . H^4 O^4

we have . . C^8 H^4 Az^2 O^{10}

which is an atom of alloxane.

The urea, as is well known, and the nitrous acid formed mutually, decompose each other into nitrite of ammonia, and free cyanic acid. The nitrite of ammonia, by a gentle heat, is decomposed into azotic gas and water; while the cyanic acid, along with the elements of water, is decomposed into ammonia and carbonic acid. Equal volumes of these two gases ought to be disengaged, while the proportion of ammonia formed by the decomposition of the cyanic acid ought to remain in the liquid. Now, as all this is what actually takes place, there can be no doubt of the accuracy of the explanation of the action of nitric acid on uric acid given by Wöhler and Liebig.

When crystals of anhydrous alloxane are dissolved in concentrated muriatic acid by the assistance of heat, we perceive an effervescence which continues till the action is complete. The products differ according to the mode of proceeding. If we only heat the solution for a few minutes it becomes muddy, and deposites on cooling a great number of brilliant and transparent crystals of alloxantin. The solution being freed from these crystals, and purified from muriatic acid by evaporation, gives crystals of oxalate of ammonia. The decomposition consists in the separation of two atoms of alloxane into oxalic acid, oxaluric acid, and alloxantin.



2 atoms alloxane $= C^{16}$ H^8 Az^4 O^{20} =

1 atom oxalic acid, $= C^2$ O^3

1 atom oxaluric acid, $= C^6$ H^3 Az^2 O^7

1 atom alloxantin, $= C^8$ H^5 Az^2 O^{10}

C^{16} H^8 Az^4 O^{20}

The oxaluric acid, by boiling with muriatic acid, is decomposed into cyanate of ammonia, the acid of which, in presence of the same agent, becomes bicarbonate of ammonia.

Alloxane treated in the same way with dilute sulphuric acid gives the same products. This is a very convenient and rapid way of obtaining alloxantin.

By a long continued boiling, the alloxantin disappears in its

turn, and a new yellow powder, scarcely soluble in water, is deposited. The same substance is often obtained when we transform alloxane into alloxantine by zinc and muriatic acid, when we employ too concentrated a solution, or continue the heat too long.

It is then deposited under the form of a yellow crust, which may be purified by washing. It dissolves readily in ammonia, and brilliant, yellow, granular crystals are soon deposited. When heated with excess of ammonia they are transformed into a yellowish jelly, very little soluble in water and ammonia.

Wöhler and Liebig dissolved in ammonia the yellow crystals obtained by the action of zinc and muriatic acid on alloxane, and neutralized the liquid by acetic acid. The yellow substance separated in a few days. The analysis of it led to the formula $C^6 H^3 Az^2 O^3 = 11{\cdot}375$.

When a concentrated solution of pure alloxane is boiled, carbonic acid is given out for a long time. It then gives with barytes a deep blue precipitate, and with carbonate of ammonia a rich crystallization of murexide. On cooling, and even during the boiling, a great quantity of alloxantin falls down, though none originally existed in the liquid. 3 atoms of alloxane gave,

2 atoms alloxantin, .	$C^{16} H^{10} Az^4 O^{10}$
1 atom parabanic acid, .	$C^6 H^2 Az^2 O^6$
2 atoms carbonic acid, . .	$C^2 \quad O^4$
3 atoms of alloxane .	$C^{24} H^{12} Az^6 O^{20}$ *

SECTION V.—OF ALLOXANTIN.

The solution of uric acid in dilute nitric acid takes place with the same phenomena as in concentrated acid. But after a gentle evaporation the liquid deposites hard transparent crystals, which are colourless, or have a slight yellow tinge. These crystals have been distinguished by Wöhler and Liebig by the name of *alloxantin.* †

Alloxantin is scarcely soluble in cold water. It dissolves, though slowly, in boiling water, but is almost wholly deposited in crystals as the solution cools. Even after five or six successive crystallizations it reddens litmus-paper; yet it wants the charac-

* Ann. der Pharm. xxxviii. 357.

† Ann. de Chim. et de Phys. lxviii. 227.

ters of an acid; for when it comes in contact with a base it is immediately decomposed.

When barytes water is added to a solution of alloxantin, a copious precipitate of a fine violet colour falls, which becomes white, and then disappears entirely when the liquor is boiled. An excess of barytes throws down a fine white precipitate. The reaction of alloxantin with nitrate of silver is very remarkable. As soon as the two liquids come in contact, a black precipitate of metallic silver falls, though no gas whatever is evolved, nor any thing else thrown down. When the liquid is separated from the metallic silver by filtration, barytes water throws down a white precipitate from it. With selenious acid it acts in the same way, a red precipitate of selenium falling.

When alloxantin is placed in an atmosphere containing gaseous ammonia, it assumes a red colour, its crystals become opaque, and lose no weight though exposed to a temperature of 212°. At a higher temperature they lose water.

Alloxantin was subjected to an ultimate analysis in Liebig's laboratory. The mean of four different analyses gave

Carbon,	30·06 or	8 atoms =	6·0 or per cent.	29·82
Hydrogen,	3·16 or	5 atoms =	0.625 ...	3·10
Azote,	17·53 or	2 atoms =	3·5 ...	17·40
Oxygen,	49·25 or	10 atoms =	10·0 ...	49·68
	100·00		20·125	100·

This gave the formula $C^8 H^5 Az^2 O^{10} = 20{\cdot}125$. So that alloxantin differs from alloxane by containing an additional atom of hydrogen.

When alloxantin is formed in dilute nitric acid, one atom of oxygen only instead of two unites to the elements of the acid, $C^8 Az^2 O^4$, which, united to urea, constitutes uric acid. Hence the nitric is converted into nitrous acid ($Az O^4$.) This acid, by the contact of water, is decomposed into hyponitrous acid ($Az O^3$), and nitric acid ($Az O^5$); only one of these decomposes the urea. The consequence is, that a quantity of urea remains undecomposed in the liquid. Accordingly, if we add nitric acid, crystals of nitrate of urea are deposited.

When alloxane is treated by deoxygenizing bodies, it is converted into alloxantin. Thus, if we pass a current of sulphuretted hydrogen gas through a moderately concentrated solution of

alloxane, the liquid becomes muddy, and a precipitate of pure sulphur falls. Soon after a white crystalline powder is deposited, and if the solution of alloxane was concentrated, the liquor assumes the form of a thick magma of crystals of alloxantin. When the precipitate is treated with boiling water it dissolves, with the exception of the sulphur, and deposites a large quantity of alloxantin in white transparent crystals.

We convert alloxane into alloxantin also by adding to its solution a little muriatic acid, and then introducing a piece of zinc. After an interval of some hours a considerable deposite of alloxantin makes its appearance under the form of a crystalline crust.

Protochloride of tin likewise throws down alloxantin from a solution of alloxane.

On the other hand, when alloxantin is treated by oxygenizing bodies, it is converted into alloxane. If we add a few drops of nitric acid to a solution of it, a slight effervescence is observed, and the products of the decomposition of that acid are given out. When the liquid is evaporated to the consistence of a syrup it congeals into a crystalline mass, which, being dissolved in water, the solution, when evaporated, spontaneously deposites colourless crystals of alloxane.

Alloxantin does not produce anything else than alloxane: no ammonia nor any other substance is evolved.

When ammonia is added to a hot solution of alloxantin it becomes purple; but the colour disappears by the action of heat, and also some time after the hot solution is allowed to cool. When ammonia is added to alloxane, scarcely a sensible change of colour takes place. When we add nitric acid to alloxantin, drop by drop, we observe, when we saturate a portion of it from time to time with ammonia, and heat it a little, that the solution acquires a more and more intense purple colour. After the addition of a certain quantity of nitric acid, and afterwards of ammonia, the purple colour becomes so deep that the liquid loses its transparency. But if more than a certain proportion of nitric acid be added, this property disappears.

A solution of uric acid in dilute nitric acid treated immediately by ammonia does not acquire a purple colour, or at least speedily loses it again. The same solution subjected during some minutes to boiling, or even gentle heat, takes with ammonia a deep purple colour, and gives a considerable quantity of the

beautiful cantharides green crystals constituting the purpurate of ammonia of Prout. But we do not obtain them, if we continue the heat beyond a certain time; the solution even loses the property of becoming coloured with ammonia. The reason of these phenomena is obvious: the solution of alloxantin treated with a certain quantity of nitric acid and ammonia furnishes the green crystals. But when all the alloxantin is converted into alloxane by the action of the nitric acid, these crystals cease to make their appearance.

Nitrate of silver converts alloxantin into alloxane, by giving out an atom of oxygen, which forms water with the additional atom of hydrogen, while the silver is precipitated in the metallic state.

SECTION VI.—OF URAMILE.

Pure *uramile** is obtained by boiling for some minutes a mixture of thionuric acid or thionurate of ammonia, and dilute sulphuric or muriatic acid. The solution, even though dilute, concretes at that temperature into a white magma consisting of very minute brilliant needles. This magma is easily washed, and diminishes enormously in volume when dried.

Uramile may be prepared exceedingly beautiful by dissolving thionurate of ammonia in cold water, heating the solution to the boiling point, adding the requisite quantity of muriatic acid, keeping the mixture boiling for a few minutes, and then allowing it to cool. In this case the uramile is formed slowly, and crystallizes in long brilliant hard needles, having a feathery form.

Dr Gregory of Aberdeen has given the following process for preparing uramile: Dissolve thionurate of ammonia in boiling water, add a small excess of dilute sulphuric acid, and boil for a short time. Even while hot uramile is deposited in large quantity. It is to be collected and dried by pressure.

Dry uramile is white, has a satiny lustre, is insoluble in cold water; but slightly soluble in boiling water, from which it separates as the liquid cools. It dissolves in ammonia and is thrown down unaltered by the addition of acids to the solution. When boiled with ammonia it is decomposed; the liquid becomes yellowish, and acquires the property of assuming a deep purple colour and of depositing green crystalline needles. Uramile con-

* Ann. de Chim et de Phys. lxviii. 261.

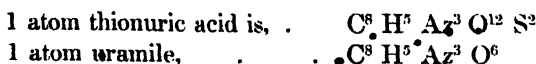
tains no sulphuric acid. By nitric acid it is decomposed with effervescence. When the solution is evaporated and saturated with ammonia, it assumes a purple colour like the solution of uric acid in nitric acid.

Uramile is soluble in potash ley and in sulphuric acid. It is precipitated unaltered from the former by acids, and from the latter by water.

When heated with oxide of copper the carbonic acid and azotic gases evolved were to each other as 8 : 3. When dried by artificial heat it assumes a slight shade of red. The mean of four analyses in Liebig's laboratory, by means of oxide of copper, gave the constituents of uramile as follows:

Carbon, .	32·83 or 8 atoms	= 6 or per cent.		33·56
Hydrogen,	3·75 or 5 atoms	= 0·625	...	3·50
Azote, .	28·72 or 3 atoms	= 5·250	...	29·38
Oxygen, .	34·70 or 6 atoms	= 6·000	...	33·56
	100·00	17·875		100·00

Thus it appears, that, at a boiling temperature, thionuric acid is decomposed into one atom of uramile and two atoms of sulphuric acid.



1 atom thionuric acid is, . $C^8 H^5 Az^3 O^{12} S^2$
1 atom uramile, . . $C^8 H^5 Az^3 O^6$



Remain $O^6 S^2$

which is equivalent to two atoms of sulphuric acid.

SECTION VII.—OF MUREXIDE. *

This is the substance which Dr Prout first obtained by adding ammonia to a solution of uric acid in nitric acid, and which he described under the name of *purpurate of ammonia*. The preparation of it was so uncertain, and depended upon so many circumstances which had not been determined, that scarcely any chemist was able to succeed in obtaining it till the subject was investigated by Wöhler and Liebig.

Dr Prout found that this substance dissolves in the alkalies while ammonia is evolved, and that the acids precipitate from its solution a white or yellow matter in fine brilliant plates. This last substance he called *purpuric acid*.

* Ann. de Chim. et de Phys. lxviii. 314.

The subsequent experiments of Vauquelin* and Lassaigne,† show only that these chemists conceived that there existed in purpurate of ammonia another substance, besides those pointed out by Prout, but which they did not obtain or characterize by any positive results.

Murexide was obtained by Wöhler and Liebig in the following manner: One part of uric acid was put into a porcelain capsule and moistened with thirty-two times its weight of water. The mixture was raised to the boiling point, and nitric acid of specific gravity 1·425 previously mixed with twice its weight of water was added by small quantities at a time, waiting till the effervescence was at an end before a new quantity was added. The addition of nitric acid was stopped when only a trace of uric acid remained. The liquid was raised to the boiling point, filtered and evaporated by a gentle heat. During this evaporation a slight effervescence was continually observed. The liquid when concentrated to a certain point became coloured. The evaporation was stopped when the liquid assumed the colour of an onion. It was cooled down to 158°, and then dilute caustic ammonia was added.

The success of the process depends upon the quantity of ammonia, and on the temperature. The liquid should contain a very slight excess of ammonia. It ought neither to be cold nor hotter than 158°; otherwise the compound is destroyed by the free ammonia and another formed. The colour of the liquid is so intense that it is opaque. We cannot therefore assist ourselves in determining the requisite proportions by the reactions of vegetable blues. The smell is the best means of determining if the quantity of ammonia added be sufficient.

Dr Gregory of Aberdeen has given the following process for preparing murexide: Dissolve seven grains of alloxane (containing its water of crystallization), and four of alloxantin in 240 grains of water by boiling, and add the hot solution to 80 minims of a cold strong solution of carbonate of ammonia. Collect the crystals after some hours, slightly wash them with cold water, and dry them by pressure between folds of paper.‡

During and after the cooling are deposited the magnificent crystals of murexide. They have a green colour and the metal-

* Jour. de Phys. lxxxviii. 258. † Ann. de Chim. et de Phys. xxii. 334.
‡ Ann. der Pharm. xxxiii. 334.

lic lustre. They are generally mixed with a red flocky powder; from which the crystals are easily freed by dilute ammonia, in which the powder is soluble.

Sometimes when the temperature, during the addition of the ammonia, has sunk too low, it was found advantageous, when the quantity of ammonia added was sufficient, to pour into the liquid its own bulk of boiling water. The crystals then were deposited slower, and were of remarkable beauty.

But the easiest process, and the one which yields murexide in the state of greatest beauty, is the following: Mix equal weights of uramile and red oxide of mercury with from twenty-four to thirty times their weight of water, add caustic ammonia to the mixture, and raise it gradually to a boiling temperature. A very little ammonia is sufficient. The solution gradually acquires an intense purple colour. When it begins to boil it is opaque, and has a thick consistence. After allowing it to boil a few minutes pass it through a filter. Generally flocks of uramile adhere to the filter. They may be washed off and heated anew with red oxide of mercury and ammonia. It yields, like the first solution, crystals of murexide. The addition of carbonate of ammonia when the liquid is almost cold generally occasions the formation of more crystals.

The crystals of murexide are always small, never exceeding three or four lines in length. They are short four-sided prisms, two of the faces of which reflect the light of a metallic green colour like the wings of cantharides, while the two other faces exhibit a mixture of brown. When seen by solar light they have a garnet red colour, and are transparent. Thus they resemble in colour the beautiful crystals of sulphomolybdate of potassium. When in powder the substance is red; but under the burnisher becomes green and assumes the metallic lustre.

Murexide is very little soluble in cold water, though it gives it a deep purple colour. It dissolves more readily in hot water. It is insoluble in alcohol and ether. A saturated solution of carbonate of ammonia scarcely takes up a trace of it. Hence this salt may be employed with advantage to purify murexide from substances which are soluble in it. It dissolves in caustic potash, assuming a fine blue colour.

The formation of murexide is the result of the action of ammonia upon the alloxane and alloxantin which exist in the nitric

acid solution of uric acid. Wöhler and Liebig have ascertained that both these substances are present, and the former in greater proportion, and that the decompositions which take place are very complicated.

If we boil a solution of alloxantin in ammonia till the colour at first induced disappears, allow the liquid to cool down to 158°, and then add a solution of alloxane, every drop we add the purple colour of the liquid increases in intensity, till at last it becomes quite opaque. Soon after we see formed on the sides of the vessel and the surface of the liquid brilliant green crystals of murexide. But the quantity of them is never proportional to that of the substances employed. Sometimes these crystals are mixed with red flocks of uramile, easily separated by washing them cold in caustic ammonia.

The principal result of the action of ammonia on alloxantin being the production of uramile, it was natural to think that the formation of murexide depended on the action of alloxane on uramile while ammonia was present. They found that when a solution of alloxantin with sal-ammoniac or oxalate of ammonia is heated till the decomposition was effected and the uramile formed, if enough of ammonia be added to redissolve the precipitate at first formed, and after that a solution of alloxane be poured in, the colour becomes very intense, and murexide separates in considerable quantity.

We obtain murexide in great beauty, though in no great quantity, when, after having decomposed alloxantin by sal-ammoniac, we filter off the uramile formed and saturate the residual liquid with carbonate of ammonia. Uramile dissolved in ammonia and treated with alloxane always gives murexide.

The co-operation of alloxantin in the production of murexide seems merely to consist in the formation of uramile; but in what way alloxane acts seems still an enigma.

Wöhler and Liebig observed that a simple solution of uramile in ammonia, evaporated by the assistance of heat, and boiled for some time, assumes a deep purple colour, and gives, on cooling, a great quantity of murexide. This would seem to prove that alloxane does not contribute to the formation of this product, but by abandoning a portion of its oxygen. This led them to try whether other substances easily parting with oxygen might not be substituted for alloxane.

They found that murexide may be prepared with great facility by putting uramile in boiling water, and adding by little and little, small quantities of oxide of silver or oxide of mercury. The oxides are reduced, the liquid assumes a deep purple colour, and when filtered yields pure crystals of murexide. No gas is given out during the process.

The slightest excess of oxide causes the red colour to disappear. The liquid becomes colourless, and contains an ammoniacal salt, which behaves with the salts of silver and barytes like alloxanate of ammonia.

When the crystals of murexide are heated, they lose between three and four per cent. of water.

The analysis of murexide occasions some difficulty, in consequence of the readiness with which protoxide of azote is formed. It was avoided by causing the gases to pass through very fine copper filings raised to the requisite temperature. The proportion of azotic gas to that of carbonic acid gas, the mean of four experiments, was 2·084 of the former, to 4·994 of the latter; or as 2 : 4·79, or very nearly as 5 : 12.

The mean of five analyses in Liebig's laboratory, by means of oxide of copper, gave

Carbon,	33·61	or 12 atoms =	9·00	or per cent.	33.97
Hydrogen,	3·00	or 6 atoms =	0·75	...	2·83
Azote,	32·70	or 5 atoms =	8·75	...	33·01
Oxygen,	30·69	or 8 atoms =	8.00	...	30·19
	100·00		26·5		100·00

The formula $C^{12}\ H^{6}\ Az^{5}\ O^{8}$ agrees very well with the analysis, and its accuracy has been corroborated by Wöhler and Liebig by the following considerations:

Murexide is obviously not an ammoniacal salt; but an amide—though a kind of amide hitherto without analogy. The problem of the exact formula would have been easily resolved, if, by its decomposition, it had only given two products like the amides. But it gives origin to five different bodies, susceptible themselves of being altered by the agents employed to destroy the murexide. This leads to the supposition that secondary products are present.

A boiling solution of murexide, treated by sulphuric or muriatic acid, deposites in a short time pearly plates, which are white,

yellow, or reddish, and which Prout has called *purpuric acid.* Liebig and Wöhler have distinguished this substance by the name of *murexane.*

SECTION VIII.—OF MUREXANE.*

We obtain this substance when we dissolve murexide in caustic potash; boil the liquid till the blue colour disappear, and then pour into it dilute sulphuric acid. To obtain it pure, we have only to dissolve the murexane thus obtained in potash, and precipitate it by an acid. It has then the form of a very light powder, very porous, having a silky lustre, and becoming red when exposed to the vapour of ammonia. It is insoluble in water and in dilute acids; but soluble without sensible alteration in concentrated sulphuric acid, from which it is precipitated by water. It dissolves readily in the alkalies and in ammonia, but without neutralizing them. When newly precipitated, it has a great resemblanee to uramile; but it is easily distinguishable both by its reaction and by its composition.

When burnt with oxide of copper, it gives azotic and carbonic acid gases in the proportion 1 : 3.

The mean of four analyses made in Liebig's laboratory gives its compositions—

Carbon,	32·76 or 6 atoms	= 4·5	or per cent.	33·33
Hydrogen,	3·73 or 4 atoms	= 0·5	...	3·70
Azote .	25·48 or 2 atoms	= 3·5	...	25·93
Oxygen,	38·03 or 5 atoms	= 5·0	...	37·04
	100·00	13·5		100·00

Murexane is not the only product of the decomposition of murexide. We find ammonia combined with the acid, which was employed to throw down the murexane. It may be driven off by the addition of a fixed alkali. If, after having decomposed murexide by dilute sulphuric acid, we separate the murexane by the filter, there remains a colourless liquid, which possesses the following characters:

When placed in contact with nitrate of silver, it assumes a black colour, and deposites in a short time metallic silver, just as would happen to a solution containing alloxantin. Ammonia forms in the liquor separated from the silver a dense white pre-

* Ann. de Chim. et de Phys. lxviii. 322.

cipitate, which becomes yellow on boiling, without dissolving. In this respect it agrees with a solution of alloxane mixed with ammonia.

If we decompose murexide by muriatic acid, separate the murexane, and add barytes water to the acid liquid, a dense precipitate falls of a light violet colour. This reaction indicates the presence of alloxantin. The precipitate is not of so deep a violet as with pure alloxantin, but it is not colourless like that from pure alloxane. A current of sulphuretted hydrogen instantly destroys the colour of the murexide. Silky plates of murexane precipitate; and the liquid gives with barytes water a deep violet precipitate, while ammonia is disengaged. It is obvious that the alloxane become free is changed by the sulphuretted hydrogen into alloxantin.

When we boil murexide with a solution of potash till the deep indigo blue colour disappear, precipitate the murexane by muriatic acid, and neutralize the liquid exactly with ammonia, it does not precipitate the salts of lime and barytes. But if we add a new dose of ammonia, dense white flocks fall, which disappear when we add a large quantity of water. This reaction characterizes the alloxanates of lime and barytes.

If, after having decomposed murexide by dilute sulphuric acid, we pour barytes water into the cold liquid, as long as a precipitate continues to fall, the whole sulphuric acid, and along with it all the alloxane and alloxantin, except a mere trace, are precipitated. The filtered solutions being treated with carbonate of ammonia to separate the free barytes, filtered anew, and evaporated to a small bulk, gives with nitric acid crystals of nitrate of urea.

The solution obtained by the decomposition of murexide by means of sulphuric acid being neutralized by carbonate of ammonia, and evaporated in a very gentle heat, loses, after some time, the red colour which it had assumed. It gives a crystalline mass, in which it is easy to recognize alloxanate of ammonia mixed with sulphate. The same solution being treated with ammonia and a salt of silver, gives a white precipitate, which, by the action of a gentle heat, becomes black while gas is disengaged, and is reduced to metallic silver.

From all these reactions, it results that murexide produces, by its decompositions by acids and alkalies, five different products,

namely, ammonia, murexane, alloxane, alloxantin, and urea. Wöhler and Liebig consider it as a combination of various amides. Yet the decomposition of thionurate of ammonia when decomposed by the acids gives a greater number of products than even murexide.

CHAPTER II.

OXIDES NOT CONTAINING AZOTE, AND NOT OILY.

These bodies have been hitherto very imperfectly investigated. We can enumerate in the present state of our knowledge only four such substances, namely,

1. Melain.
2. Oönin.
3. Diabetes sugar.
4. Sugar of milk.

These bodies will constitute the subject of the following sections:

SECTION I.—OF MELAIN.*

This name has been given by Bizio to the black matter which constitutes the essential constituent of the ink of the cuttle-fish. It was first examined by Mr G. Kemp† in the year 1813, afterwards by Dr Prout in 1815;‡ and finally by Bizio.§

The black liquor of the cuttle-fish is secreted in a bag or bladder situated near the cæcum, which communicates by a narrow duct, with an opening in the upper part of the belly of the fish. When chased by other fishes, the cuttle-fish is said to discharge a quantity of this liquid, which, by rendering the water muddy, enables it to escape from its enemies. Dr Prout found that when the black matter in this ink is mixed with water, it takes at least a whole week to subside. It is therefore admirably adapted for the purposes of concealment.

The ink of the sepia when fresh is a black glairy liquid, of a viscid consistence, a peculiar fishy smell, and very little taste. When allowed to dry in its bladder, it becomes hard and brittle, has an imperfectly conchoidal fracture, a brownish-black colour, and exhibits a slight peacock-tail lustre on exposure to a strong

* From μελας, black.

† Nicholson's Jour. xxxiv. 34.

‡ Annals of Philosophy, v. 417.

§ Brugn. Jour. xviii. 18.

light. When in powder, it has a fine velvet black colour, has no smell, it taste is saltish, and its specific gravity about 1·640.

Dr Prout analyzed a portion of this dry matter, and found its constituents as follows:

Melain,	78·00
Carbonate of lime,	10·40
Carbonate of magnesia,	7·00
Common salt? } Sulphate of soda, }	2·16
Mucus,	0·84
	98·40

Melain has a fine full black colour, and possesses the shining appearance of powdered charcoal. It is insoluble in muriatic and sulphuric acids, even when assisted by heat; and also in acetic acid. Concentrated nitric acid acts on it readily, and with considerable energy, abundance of red fumes being emitted, and at length a partial solution being formed of a very deep reddish-brown colour. Potash added to this solution occasions no precipitate; but carbonate of potash occasions a slight one. Caustic potash ley, when assisted by heat, effects a partial solution of melain. So does caustic ammonia, but in a slighter degree. The colour of these alkaline solutions is a darker brown than of the solutions in nitric acid. When muriatic or sulphuric acid is dropt into the alkaline solution, a slight precipitate falls; but this does not happen when nitric acid is employed.

Melain burns without melting and with considerable difficulty, emitting the usual smell of burning animal matters, somewhat modified by a fishy odour. When burnt, it left a minute portion of reddish ashes, consisting of a mixture of peroxide of iron, lime, and magnesia.

Melain is insoluble in water, but mixes with that liquid readily and remains long suspended; but the addition of the mineral acids or ammonia causes it to subside rapidly. It is insoluble in alcohol and ether.

Melain may be obtained from the dried ink of the cuttle-fish by boiling that substance in water till every thing soluble in that liquid is taken up. It is then treated in the same way successively by alcohol and muriatic acid. Thus purified, it is to be well-washed with water, containing towards the end a little carbonate of ammonia.

SECTION II.—OF OÖNIN.

This name (from ὠον, an egg,) has been given to a peculiar principle which M. Couerbe extracted from the albumen of an egg in the year 1829, and to which he gave at first the name of *albuminin*, but afterwards changed for *oönin*.*

M. Couerbe left a concentrated solution of albumen from an egg in water, in a temperature varying from 32° to 18°. The solution became thick without congealing, and in about a month deposited a membranous net-work, which was pretty abundant.

This membranous matter is solid, white, translucent, composed of membranes, tasteless, and without smell. It was easily reduced to powder.

When heated in a glass tube, shut at one end, it is decomposed without melting, and yields no ammonia. During its calcination it swells, and leaves a bulky charcoal difficult to burn. When decomposed by oxide of copper and heat, it gives nothing but water and carbonic acid gas.

It is insoluble in water, though it is softened by that liquid. In boiling water it swells without dissolving, and assumes the appearance of insoluble mucor.

Alcohol, ether, and acetic acid have no action on it whatever, either cold or hot. It swells slightly in concentrated sulphuric acid while cold; but if we apply a gentle heat, the oönin is rapidly charred, and gives out an agreeable smell. When water is added, the charred matter precipitates, leaving a colourless dilute acid. Cold nitric acid acts but feebly on oönin; but when heat is applied, it dissolves it with the evolution of deutoxide of azote. The best solvent of oönin is hot muriatic acid. The solution is colourless, and no precipitate falls when it cools; but if we add water, the liquid becomes muddy, and a white precipitate falls in the state of a very fine powder.

Alcoholic solution of potash dissolves it with the assistance of a little heat. When the liquid cools no precipitate appears. If we saturate the alkali with muriatic acid, the mixture becomes muddy; but no precipitate falls during twenty-four hours. These experiments of Couerbe were repeated and confirmed by MM. Soubeiran, and Henri, Jun.†

* Ann. de Chim. et de Phys. xli. 323.

† Jour. de Pharm. xv. 495, and xix. 299.

SECTION III.—OF DIABETES SUGAR.

It is now universally known that in the disease called *diabetes*, the urine contains a considerable quantity of *sugar*, which may be easily extracted in a state of purity. The sweet taste of diabetic urine, and, of course, the existence of sugar in it, seems to have been first observed by Dr Willis. Sydenham, though he describes the disease, and distinguishes it by the name of diabetes, takes no notice of the sweet taste of the urine, but only of its great quantity.* The first person who attempted to obtain the sugar in a separate state was Mr Cruikshanks. He gives an account of his experiments in an appendix to Dr Rollo's book on Diabetes, which was published in 1797. He extracted from diabetic urine about one-twelfth of its weight of a sweet tasted extract like honey.

In 1815, Chevreul† analyzed diabetic urine, and extracted from it the sugar in a state of purity. He found that the shape of the small crystals which it formed (small spherules) was precisely the same as that of grape sugar. It possessed all the qualities of that sugar, has the same solubility in water and alcohol, and like grape sugar melts when exposed to a gentle heat. From these facts, Chevreul concluded that diabetic sugar was precisely the same with that of grapes. Cruikshanks had already compared it to honey; and we now know that sugar of honey is identical with that of grapes. M. Calloud ‡ found diabetic and grape sugar to agree also in another property, namely, that of combining with common salt and forming crystals which have the form of dodecahedrons composed of two six-sided pyramids applied base to base, or sometimes of rhomboids. According to Calloud these crystals are composed of,

Common salt,	8.3
Sugar,	91·7
	100·

This differs essentially from Brunner's analysis, which I have given in the Chemistry of Vegetables, p. 638. Calloud's analysis would indicate four atoms of sugar to one of common salt, while Brunner's make the compound to consist of an atom of each constituent. But when he combined common salt directly with

* Opera, p. 271.

† Ann. de Chim. xcv. 319.

‡ Jour. de Pharmacie, xi. 562.

sugar of grapes, he obtained a compound exactly coinciding with Brunner's, since it consisted of,

Common salt,	.	28
Sugar,	.	75
		100

In some rare cases of diabetes, the quantity of common salt in the urine is so great, that, by evaporating it by a gentle heat, crystals are deposited consisting of common salt combined with diabetes sugar.

Sugar of diabetes was first analyzed by Dr Prout.* He found it composed of

Carbon,	36·	to	40·
Hydrogen,	7·11	to	6·66
Oxygen,	56·89	to	53·34
	100·00		100·00

But these differences are too great to enable us to deduce the constitution of diabetes sugar from the analysis. Peligot† analyzed diabetes sugar with great care in 1838, and found its constituents to be

Carbon,	.	35·88
Hydrogen,	.	7·44
Oxygen,	.	56·68
		100·00

This gives the formula,

12 atoms carbon,	.	= 9·00	or per cent.	36·36
14 atoms hydrogen,		= 1·75	...	7·07
14 atoms oxygen,		= 14·00	...	56·57
		24.75		100.00

This is obviously the same constitution which sugar of grapes has. By heat diabetes sugar may be deprived of two atoms of water, and thus it becomes,

* Phil. Trans. 1827, p. 373. † Ann. de Chim. et de. Phys. lxvii. 142.

12 atoms carbon, .	= 9·0	or per cent.	40·
12 atoms hydrogen,	= 1·5	...	6·66
12 atoms oxygen,	= 12·	...	53·34
	22·5		100.00

I found that, by combining it with certain bases, it might be deprived of another atom of water, and thus reduced to

12 atoms carbon,	= 9·	or per cent.	42.11
11 atoms hydrogen,	= 1·375	...	6·43
11 atoms oxygen,	= 11·	...	51·46
	21·375	...	100·

Thus it is identical with grape sugar in its constitution. Hence the reason why diabetic urine is so apt to ferment and evolve alcohol.

SECTION IV.—OF SUGAR OF MILK.

Sugar of milk may be extracted from whey in the following manner : Evaporate the whey to the consistence of a syrup, and set it aside for some weeks in a cool place. Granular crystals of sugar of milk will be deposited. To obtain it pure we must redissolve it in water, and crystallize it a second time. And this process must be repeated two or three times.

Fabricius Bartholetti, an Italian, was the first European who mentioned this sugar. He described it in his *Encyclopædia Hermetica-Dogmatica*, published at Boulogna in 1619 ;* but it seems, from what Haller says, to have been known in India long before that time. It is manufactured in large quantities in Switzerland, from which country all the sugar of milk of commerce comes. The person who chiefly contributed to make sugar of milk generally known, was Ludovico Testi, who gave it out as an invention of his own, and sold it as a powerful remedy in the gout and other diseases. He was a physician in Venice, where he died in 1707. After his death Valisneri published the process which Testi employed in extracting his sugar from whey.

Sugar of milk is white, and crystallizes in right four-sided prisms, usually terminated by four-sided pyramids. It has a

* According to Beckman, he called it *manna, seu nitrum seri lactis*. History of Inventions, ii. 494.

taste only slightly sweetish. Its specific gravity at the temperature of 55° is 1·543. At 59° it is soluble in 5 times its weight of water, and 2½ times its weight of boiling water. When the crystals are melted they lose 12 per cent. of water. When thus fused the sugar is transparent and colourless. On cooling it concretes into a white opaque mass. It dissolves but slowly in water. But the solution may be evaporated much beyond the crystallizing point without any crystals forming. It is scarcely soluble in absolute alcohol; but its solubility is increased when the alcohol is diluted with water. In ether it is insoluble. When long boiled in dilute sulphuric acid it is converted into sugar of grapes. Nitric acid converts it into oxalhydric, oxalic, and mucic acids. When in powder it absorbs muriatic acid gas in great quantity, and assumes the form of a grey coherent mass. It absorbs also ammoniacal gas, and when completely saturated the weight augments from 100 to 112.4 or the compound of sugar of milk and ammonia is composed of,

Sugar of milk,	.	100·	or 17.137
Ammonia,	.	12·4	or 2·125

Caustic potash converts it into a brown, bitter tasted substance, which is insoluble in alcohol.

When digested with oxide of lead at a temperature not exceeding 122°, a combination takes place. The liquid is a solution of oxide of lead holding in suspension an insoluble compound, which may be obtained by filtering in a covered vessel to exclude the carbonic acid of the atmosphere. It is mucous, and when dried becomes gray and translucent. At 212° it loses water and becomes yellow. It is composed of,

Sugar of milk,	.	36·47	or 8.018
Oxide of lead,	.	63·53	or 14·
		100·00	

The filtered liquid contains a soluble compound of sugar of milk, and oxide of lead. Its taste is at once sweet, alkaline, and styptic. When evaporated in vacuo it leaves a yellow transparent substance resembling gum, which is soluble in water. It is composed of,

Sugar of milk,	.	81·88	or 63·117 = 8.018 + 8
Oxide of lead,	.	18·12	or 14·
		100.00	

If we add ammonia to the soluble compound, the insoluble compound, noticed above, falls down. If we digest it for a long time with an excess of oxide of lead we obtain a subsalt composed of,

Sugar of milk,	12·55 or 8
Oxide of lead,	87·45 or 55·74 = 14 × 4
	100.00

Sugar of milk was first subjected to an ultimate analysis by Gay-Lussac and Thenard.* Berzelius analyzed it in 1815,† Prout in 1827,‡ Liebig in 1834,§ and Brunner in 1835.‖ The following table exhibits the result of these analyses:

	Gay Lussac and Thenard.	Berzelius.	Prout.	Liebig.	Brunner.	Mean.
Carbon,	38·825	39·474	40.00	39 51	40·437	39·649
Hydrogen,	7·341	7·167	6·66	6·74	6·711	6·926
Oxygen,	53·834	53·359	53·33	53.75	52·852	53.425
	100·000	100·000	100·00	100 00	100·000	100·000

These experiments exhibit the constitution of sugar of milk in crystals. They lead to the formula,

12 atoms carbon	= 9	or per cent.	40
12 atoms hydrogen	= 1·5	...	6·66
12 atoms oxygen	= 12·0	...	53·33
	22·5		100·00

But, according to Berzelius, 100 parts of crystals of sugar of milk when dried at 212°, or when combined with oxide of lead, lose 12 of water. Hence 22·5 would lose 2·7 of water or $2\frac{1}{3}$ atoms. Let us suppose the loss to be only 2.25 or two atoms water, then it would follow that anhydrous sugar of milk is composed of,

12 atoms carbon,	= 9	or per cent.	44·44
10 atoms hydrogen,	= 1·25	...	6·18
10 atoms oxygen,	= 10·	...	49·38
	20·25		100·00

This is precisely the constitution of anhydrous cane sugar. Yet the properties of the two differ exceedingly from each other.

* Recherches Physico-Chimiques, ii. 295.

† Annals of Philosophy, v. 266.

‡ Phil. Trans. 1827, p. 383.

§ Annalen der Pharmacie, ix. 24.

‖ Poggendorf's Annalen, xxxiv. 335.

It is a generally received opinion that sugar of milk is incapable of fermenting, or of being decomposed into carbonic acid and alcohol. But the well-known fact, that the Tartars and the inhabitants of the Shetland Islands make an intoxicating liquor by fermenting milk, is inconsistent with this opinion, and proves that sugar of milk when properly treated may be made to ferment as well as common and grape sugar. Doubtless, like common sugar, it is first converted into sugar of grapes before it can be capable of fermenting or of being decomposed into alcohol and carbonic acid.

CHAPTER III.

OF OILY OXIDES, SAPONIFIABLE.

THE terms *fat, tallow, suet, lard*, &c. are applied to a secretion of an oily nature, usually solid in the hot-blooded, and fluid in cold-blooded animals. This substance is deposited in the cellular substance. The quantity formed depends in some measure upon the food; and when the food becomes deficient, or the power of digestion imperfect, the fat disappears. It is deposited in the cellular tissue of all animals, but the fat of only a small number of species has hitherto been examined by chemists. Of these the following are the most important:—

1. HOG'S LARD.

This is the fat of the *Sus scrofa*, or common hog. It is deposited to a considerable thickness immediately under the skin of the domestic animal. It is white, and has very little smell; but when we melt it in contact of boiling-water, the smell becomes strong and disagreeable. It melts completely at 99°, and then has the appearance of a transparent and nearly colourless fixed oil. A thermometer placed in it sinks gradually to 80°. The lard then begins to congeal, and the thermometer remains at 80° all the time of congealing, which occupies several minutes. It is clear from this that 80° is the melting point of hog's lard. Its specific gravity at 102° is 0·9028; at 60° it is 0·9302.

When hog's lard is left exposed to the air, it becomes gradually yellow-coloured and rancid, acquires a strong smell, and reddens vegetable blues. A volatile fatty acid is developed, the

nature of which has not yet been examined, but Chevreul considers it as analogous to *caproic* acid.

Hog's lard, like all the other varieties of fat, has been shown by Chevreul to consist of two distinct oily bodies; the one solid at the ordinary temperature of the atmosphere, and the other liquid at the same temperature. The first on that account has been called *stearin*; the second *elain*. Braconnot showed that if hog's lard be subjected to pressure between folds of blotting-paper, the elain is absorbed by the paper while the stearin remains. According to his experiments, hog's lard is composed of

Elain,	.	62
Stearin,	.	38
		100

The elain has a specific gravity of 0·915. 100 parts of absolute alcohol dissolve 123 parts of it.

The stearin is without smell, translucent, dry, and granular. It melts when heated to 109½°. On congealing, it assumes an imperfectly crystallized texture.

It has been shown that stearin is a compound analogous to a salt, consisting of *stearic acid* combined with *glycerin*. In like manner, elain is a compound of oleic acid and glycerin. If we digest lard with caustic potash ley, the acids gradually combine with the potash, and constitute with it a soap while the glycerin is disengaged. In this way it has been ascertained that pure lard is composed of

Stearic and oleic acids,		94·65
Glycerin,	.	9

When hog's lard is digested with nitric acid it is converted into oleic and margaric acids.*

2. OX FAT.

The fat of oxen has a yellowish-white colour, and a slight but peculiar smell. It melts when heated to 100°. Boiling alcohol of 0·821 specific gravity dissolves about the fortieth part of its weight of this fat.

Like hog's lard it is a mixture of stearin and elain. But, as it is much firmer and harder than lard, we might infer that the proportion of stearin which it contains is much greater than in

* Bussy and Lecanu, Jour. de Pharm. xii. 605.

lard. And this is the case. The stearin constitutes about three-fourths of ox tallow. It is now separated on a great scale to be manufactured into candles. The method employed is to melt the tallow, and to stir it incessantly while in the act of congealing. It is then exposed to pressure in woollen cloths at the temperature of 95°. The elain forced out still retains a considerable quantity of stearin. This elain is cooled down a few degrees below 95°, and subjected to pressure again, by which an additional portion of stearin is obtained. And this process is repeated sinking the temperature every time, till at last it is reduced as low as 36°. At last an elain is obtained, which is quite liquid, and which does not become solid though cooled down several degrees below 32°.

The stearin thus obtained is white, granular, and crystalline. It melts at 111°, and may be cooled down to 102° before it begins to congeal; but then the temperature rises to 111°, and continues so till the whole stearin is congealed. This stearin has about the same translucency as white wax. Its feel is not greasy, and it burns with a light similar to that of wax; 100 parts of absolute alcohol at the boiling temperature dissolve 15·48 parts of it.

The elain from ox fat is colourless, and almost without smell. Its specific gravity is 0·913. 100 parts of absolute alcohol dissolve 123·4 of it at the temperature of 167°.

Candles made of the stearin of ox tallow are little inferior to wax candles. The stearin being brittle and apt to crystallize, it has been found necessary to mix it with a little white wax, in order to deprive it of these qualities.

There is an oil obtained from the feet of oxen, and therefore known in this country by the name of Neat's Foot Oil, which deserves to be noticed. It remains liquid though cooled down to below 32°, and therefore is used very much to oil machinery, in order to diminish friction.

To obtain it the hair and hoofs are removed, and the inferior part of the bone of the foot being rasped down is boiled in water together with the surrounding parts. The oil swims on the surface of the water. It is nearly colourless, and may be kept a considerable time without alteration; but at last it deposites some solid matter having the aspect of stearin.

3. MUTTON SUET.

This is the name by which the fat of the sheep (*Ovis aries*)

is known in this country. It resembles ox fat, but is whiter. When fresh it has hardly any smell. Some varieties of it melt at 100°; others not till 104°, or even 106°. It dissolves in 44 times its weight of boiling alcohol of 0·821 specific gravity.

Its stearin is white and without lustre. It begins to solidify, at 99½°, and the temperature then rises to 111°. On congealing it crystallizes imperfectly. It is translucent. One hundred parts of boiling absolute alcohol dissolve 16·09 of it. The elain of mutton suet is colourless, has a slight odour of mutton, and a specific gravity of 0·913. One hundred parts of absolute alcohol dissolve 80 parts of it at the temperature of 167°.

4. GOAT FAT.

This fat resembles that of the ox, but it has a peculiar and disagreeable smell, similar to that of the animal. It is owing to the presence of a peculiar oily matter to which Chevreul has given the name of *hircin*, and which has been very imperfectly examined. It exists also in small quantity in mutton suet. It is liquid, and is found in the elain when goat fat is separated into elain and stearin. Though *hircin* has not yet been obtained separate from elain, Chevreul succeeded in obtaining *hircic acid*, which is presumed to be one of the constituents of hircin. He obtained it in the following way: Four parts of goat fat were saponified by digestion in one part of hydrate of potash dissolved in four parts of water. The soap is decomposed by phosphoric or tartaric acid. The fatty acids are separated and washed, and the washings mixed with the acid residue of the decomposed soap. This liquid is distilled.* The liquor that passes over contains the hircic acid. Saturate it with carbonate of barytes and evaporate to dryness, and decompose by distilling it with equal weights of sulphuric acid and water. The hircic acid will be found swimming on the water in the receiver under the form of a colourless volatile oil.

5. HUMAN FAT.

This fat is softer than either ox fat or mutton suet. It has a yellow colour, and its melting point seems to vary. Chevreul found fat from the kidney, when melted at 104°, begin to congeal at 77°. At 75½° it was semifluid, and at 62½° it was con-

* If the matter in the recipient leaves any stain on platinum foil when evaporated, it must be distilled again.

gealed into a mass in which might be distinguished a white solid matter and a yellow oil. Another specimen from the thigh continued quite fluid at 59°. When kept for some days at that temperature in a close flask it deposited a solid matter; but after an interval of a fortnight it was still partly liquid, a yellow oil floating on the solid portion. These variations in the congealing point depend upon a variation in the proportion of the stearin and elain in this fat.

Human fat is soluble in 40 times its weight of hot alcohol of 0·821. On cooling the liquid deposites stearin, which, after being again dissolved in hot alcohol and deposited, and exposed to pressure between the folds of blotting-paper, possesses the following properties: It is colourless, has little lustre, and melts at 122°. It may be cooled down to 106° before it begins to congeal, but the instant congelation begins the heat rises to 120°. The stearin crystallizes in a mass composed of small needles. One hundred parts of boiling absolute alcohol dissolve 21·5 of this stearin. But the greatest part precipitates when the solution cools. The elain is a colourless oil which remains liquid though cooled down to 25°, but congeals into needles at a few degrees below that temperature. Its specific gravity at 59° is 0·913. It has no smell but a sweetish taste. One hundred parts of boiling alcohol dissolve 123 of this elain, and the solution becomes muddy when cooled down to 170½°.

One hundred parts of human fat when saponified yield,

Margaric and oleic acids,	95·24 to 96·18
Glycerin, . .	9·66 to 10

The mixture of margaric and oleic acids melt between 88° and 95°. The stearin gives 8·6 of glycerin with 94·9 of fatty acids, in which there is no stearic acid, and which melt at 124°. The elain gives 9·8 of glycerin and 95 of fatty acids fusible at between 93° and 95°.

Fourcroy described under the name of *adipocirin*, a fat obtained from dead bodies which had been long piled up together, and which he considered a combination of a peculiar fatty matter with ammonia. Chevreul has shown that it is merely human fat saponified (doubtless by ammonia); and of course a combination of margaric and oleic acids with ammonia.

6. GOOSE FAT.

It is colourless, and has a peculiar taste and smell, rather agree-

able. If melted it congeals at 80½° into a granular mass, having the consistence of butter. When exposed to pressure between folds of blotting-paper at 28½° it is resolved, according to Braconnot, into,

Stearin,	.	32 fusible at 111°
Elain,	.	68
		100

The elain is yellowish white, and has a peculiar taste. One hundred parts of boiling absolute alcohol dissolve 36 parts of the stearin. When saponified it yields,

Margaric and oleic acids, .	94·4
Glycerin, . . .	8·2

The specific gravity of the elain is 0·929. One hundred parts of absolute alcohol at 167° dissolve 123½° of it. It begins to precipitate when cooled down to 124°. When saponified it gives 89 per cent. of fatty acids.

7. DUCK FAT.

It melts at 77°. Braconnot resolved it into

Stearin,	.	28 fusible at 126½°
Elain,	.	72
		100

The elain has the peculiar taste and smell which characterizes duck fat.

8. TURKEY FAT.

It was resolved by Braconnot into,

Stearin,	. .	26 fusible at 113°
Elain,	. .	74
		100

9. WHALE OIL.

This well known oil is obtained by boiling the blubber of the *Balena misticetus* or great northern whale. Its colour is brown, and it has a disagreeable fishy smell. Its specific gravity is 0·927. It boils at about 620°. When distilled over we obtain a much more fluid brown oil which boils at 410°.

When cooled it deposites stearin, which may be separated by the filter. When boiled in alcohol it becomes deeper coloured, and the elain is separated. One hundred parts of absolute alcohol dissolve at a boiling temperature 55¼ of stearin. When the solution is cooled it deposites first white brilliant crystals, and then yellowish coloured crystals, and there remains a thick brown liquor, which has not been examined. When this stearin is saponified we obtain glycerin, some phocenic acid, and 38·9 per cent. of fatty acids.

The elain is not decomposed by alcohol. One hundred parts of boiling absolute alcohol dissolve 122 parts of it. When treated with half its weight of hydrate of potash it is easily saponified; glycerin being evolved together with a little phocenic acid and margaric and oleic acids. The oleic acid has a fishy smell, which it communicates to its salts.

10.—OIL OF THE DELPHINUS PHOCENA OR PORPOISE.

This oil is liquid, and has a yellow colour. It has at first a fishy smell, which goes away when the oil is exposed to the sun and air. Its specific gravity is 0·937. When exposed to the air it acquires at first a brown colour, which gradually disappears. It then acquires the smell of oil of colza, and reddens vegetable blues. 100 parts of boiling alcohol of 0·821 dissolve 20 parts of the oil; but the solution becomes muddy on cooling. But when we boil together equal parts of the oil and alcohol, no precipitate appears, and we may add more oil almost in any proportion.

When saponified this oil yields,

Margaric and oleic acids,	.	82·2
Glycerin,	. .	16

Together with a certain quantity of phocenic acid.

11.—OIL OF DELPHINUS GLOBICEPS.

This oil is fluid, and has a light lemon-yellow colour, and a fishy smell. Its specific gravity is 0·918. 100 parts of absolute alcohol at 68° dissolve 123 parts of it. When cooled slowly to the point of congelation, or a little below it, this oil deposites a *cetin*, similar to that from the *Physeter macrocephalus*, but not quite identical with it.

When melted, this cetin begins to congeal at 114°, and it is

totally solidified at 110°. 100 parts of boiling alcohol of the specific gravity 0·834 dissolve 2·9 parts of it. It is not so easily saponified as the cetin of the macrocephalus, furnishes less ethal, and a greater quantity of fatty acids. The ethal from this oil melts at 116½°, while that from the macrocephalus melts at 118½°.

The oil from which this cetin has been deposited is perfectly liquid at 68°, and at 59° resembles butter. Its specific gravity is 0·924; 100 parts of alcohol of 0·820 dissolve 149.4 parts of it before beginning to boil. By saponification, 100 parts of this oil give 66 parts of margaric and oleic acids, along with which are 14·3 of a fat not saponifiable, and similar to ethal, only more fusible, and in fact composed of two fats, of which one melts at 80½°, and the other at 95°. They may be separated from the fatty acids by the same means as those employed to isolate the ethal. The saponification produces also 15 parts of glycerin, and a considerable quantity of phocenic acid.

12.—FAT OF COCCUS CACTI OR COCHINEAL INSECT.

In the year 1818, MM. Pelletier and Caventou made a set of experiments on the fat of this insect.* It was extracted by them by means of ether, which forms with it a yellow solution; the ether being evaporated away, the fat remains. To obtain from it a colourless stearin, we must dissolve it repeatedly in water, and crystallize it. The crystals are white pearly plates. This stearin melts at 104°, and is but little soluble in cold alcohol. When we distil off the alcohol, a little solid fat separates, and there remains an elain, which continues liquid at 32°, and which is coloured yellowish-red by the colouring matter of the cochineal insect. It still retains a small quantity of stearin in solution. This elain is easily saponified. It gives fatty acids, and a volatile odorous acid. The *Coccus polonicus* contains more fat than the *Coccus cacti*. Two specimens of it, the one moist and the other dry, were examined by Berzelius, who found the acids which they yielded similar to those in butter.†

All these fatty or oily substances from animals, and many others which have not hitherto been examined, are divisible into two distinct substances, the one solid and called *stearin*, the other liquid at the common temperature of the atmosphere, and called

* Ann. de Chim. et de Phys. viii. 270.

† Traité de Chimie, vii. 551.

elain. Some fatty bodies yield oils having different properties from elain. Those that have been examined by Chevreul are Phocenin, Butyrin, and Hircin. The mode of obtaining these bodies and their properties have been already described in the *Chemistry of Inorganic Bodies*, (Vol. ii. 35.)

Chevreul analyzed the stearin and elain from different fatty bodies, as human fat, hog's lard, mutton suet, &c. He found them all compounds of carbon, hydrogen, and oxygen. But the proportions were not the same in all. Whether this difference was owing to any diversity in the various stearins and elains, or to the presence of foreign bodies in greater or smaller quantity, we have no means of determining.

It has been ascertained that stearin is a compound of stearic or margaric acid and glycerin, which performs the part of a base. Stearic acid has been shown by the analytical researches of Messrs Redtenbacher, Varrentrapp, and Bromeis * to be $C^{68}\ H^{66}\ O^5 = 64{\cdot}25$.

In its common state it is a hydrate composed of $C^{68}\ H^{66}\ O^5 + 2\ (HO)$.

Stearates of silver and lead are composed as follows:

Stearate of silver,	.	$C^{68}\ H^{66}\ O^5 + 2\ (Ag\ O)$
Stearate of lead,	.	$C^{68}\ H^{66}\ O^5 + 2\ (Pb\ O)$

The two atoms of the oxides of silver and lead taking the place of the two atoms of water in the hydrated acid.

Dr Redtenbacher also formed stearic ether, or, as it is now called, stearate of oxide of ethyle, by dissolving stearic acid in alcohol and passing a current of muriatic gas through the solution till it refused to absorb more. Its composition was

1 atom stearic acid,	.	$C^{68}\ H^{66}\ O^5$	= 64·25.
1 atom ether,	.	$C^4\ H^5\ O$	= 4·625.
1 atom water,	.	$H\ O$	= 1·125.
			70

Margaric acid was obtained by M. Redtenbacher and M. Varrentrapp by distilling stearic acid. Its constitution is $C^{34}\ H^{33}\ O^3 = 32{\cdot}625$.

Hydrated margaric acid is $C^{34}\ H^{33}\ O^3 + HO = 33{\cdot}75$.

Margarate of silver is $C^{34}\ H^{33}\ O^3 + Ag\ O$. The atom of oxide of silver taking the place of the atom of water in the hydrate.

* Annalen der Pharmacie, xxxv. 46, 65, and 86.

These two acids have an obvious relation to each other. We may consider them as consisting of a common radical, C^{34} H^{33}, united to oxygen.

Margaric acid will be . C^{34} H^{33} + O^3
Stearic acid, . . 2 (C^{34} H^{33}) + O^5

The margaric acid is a compound of one integrant particle of the radical united to 3 atoms oxygen, while the stearic acid contains two integrant particles of the radical united to five atoms oxygen.

Stearic acid was discovered by Chevreul in 1816, and called at first *margarous acid*; but he afterwards adopted the term *stearic acid*,* as more proper. To obtain it we must saponify mutton suet, ox's fat, or hog's lard. The soap must be dissolved in a weak solution of caustic potash. The solution is to be mixed with a quantity of water forty-five times as great as that of the tallow saponified. The mixture being left at rest in a temperature between 50° and 60°, there gradually falls to the bottom a pearly looking substance, which is a mixture of bistearate, bimargarate, and superoleate of potash. This substance is allowed to dry. It is then washed three times successively in eight times its weight of boiling alcohol of 0·820. The first of these, on cooling, deposites a great quantity of crystals consisting chiefly of bistearate of potash. It is rendered quite pure by repeated solutions in alcohol, and crystallizations. It is then decomposed by tartaric or muriatic acid.

Thus prepared, stearic acid melts when heated to 158°. Redtenbacher found the melting point of the stearic acid which he prepared 160°. On cooling, it crystallizes in fine brilliant needles, interlaced with each other. It is tasteless, destitute of smell, and insoluble in water. While in a liquid state, it combines with alcohol in all proportions. If at the temperature of 167°, we mix equal weights of stearic acid and alcohol, we obtain a solution which, when cooled down to 122°, crystallizes in brilliant plates. At 113° the whole congeals into a solid mass.

Ether of 0·725 density dissolves its own weight of stearic acid when assisted by heat. The solution is limpid at 140°. At 134½° it concretes into a mass formed of beautiful plates. This acid readily combines with the alkalies, and forms a soap. One

* From στεαρ, tallow.

atom of stearic acid usually combines with two atoms of base. Thus pure stearate of soda is composed of,

1 atom stearic acid,	.	= 64 25
2 atoms soda,	. .	= 8·
2 atoms water,	. .	= 2.25
		74·5

If stearin were composed of stearic acid and glycerin alone, its constitution would be, according to the analysis of Liebig and Pelouse,* modified by the subsequent investigations of Redtenbacher and Verrentrapp, †

2 atoms stearic acid,	.	$C^{136}\ H^{132}\ O^{10}$	= 128·5
1 atom glycerin,	. .	$C^{6}\ H^{7}\ O^{5}$	= 10·375
2 atoms water,	. . .	. $H^{2}\ O^{2}$	= 2·25
		$C^{142}\ H^{141}\ O^{17}$	= 141·125

But it is probable that margaric acid, and also oleic acid, &c. are very common ingredients in most varieties of stearin.

Margaric acid was first described by Chevreul in 1813, under the name of *margarin.* In 1816 he gave it the name of *margaric acid.* But it was not till 1820 that he was able to distinguish with precision margaric acid from stearic acid. The mode of obtaining margaric acid employed by Chevreul has been detailed in the Chemistry of Inorgaric Bodies, (Vol. ii. p. 125.)

Dr Redtenbacher first ascertained that, when pure stearic acid is distilled over into a receiver, it is converted into *margaric acid.* So that the stearic acid from the ox by distillation becomes the acid of human fat. Besides margaric acid there was formed margaron, and a light oily substance which Redtenbacher called (from its composition) polymo-carburetted hydrogen.

Varrentrapp found that when ox's tallow, mutton suet, hog's lard, or olive oil were subjected to distillation, the solid products obtained possessed the characters of margaric acid. They were freed from the liquid products of the distillation by pressure, and afterwards purified by repeated solutions in alcohol and crystalizations, and finally they were saponified by soda, and precipitated by means of muriatic acid. The distilled product contained also margaron and an oily carbohydrogen.

* Ann. de Chim. et de Phys. lxiii. 148.

† Annalen der Pharm. xxxv. 46.

M. Bromeis found that when nitric acid is digested on stearic acid, a violent action takes place, which becomes gradually more moderate, and at last nearly ceases. The stearic acid after this action becomes clear and liquid, and forms a tallowy, solid matter, which melts at 95° or 113°, according to the duration of the process. This tallowy matter is margaric acid, mixed with a product proceeding from the oleic acid present, which is easily saponified by potash. It then assumes a blood-red colour, and retains that colour after separation by an acid. The tallowy mass separated from this body was freed from nitric acid by boiling it in water. It was then dissolved in hot alcohol, and allowed to cool. The margaric acid was deposited in crystals. It was purified by repeated solutions in alcohol, by saponification and precipitation by an acid.

Margaric acid resembles stearic acid very closely; but it melts at 140°, according to Chevreul, or 141°, according to Bromeis; while stearic acid requires for fusion the temperature of 158° or 160°.

The constitution of this acid, and its analogy to stearic acid, have been already pointed out. The common base is $C^{34} H^{33}$.

Margaric acid is $C^{34} H^{33} + O^3 = 32{\cdot}625$

Stearic acid, . $2(C^{34} H^{33}) + O^5 = 64{\cdot}25$

Margaric acid, in its hydrous state, contains only 1 atom water, while stearic contains 2. Hence the former combines with only 1 atom of base, while the latter combines with 2. We might also represent the constitution of these acids thus:

Margaric acid, $C^{34} H^{33} + O^3 = 32{\cdot}625$

Stearic acid, $C^{34} H^{33} + O^{2\frac{1}{2}} = 32{\cdot}125$

According to that view of their constitution, both, in the hydrous state would contain 1 atom of water, and both would combine with 1 atom of base.

CHAPTER IV.

OF OILY OXIDES NOT SAPONIFIABLE.

The oily bodies from the animal kingdom not capable of being converted into soap are not numerous, and have been but

imperfectly examined. The most important of them are *Margaron*, *Ethal*, and *Cholesterin*, of which an account will be given in the following sections.

SECTION I.—OF MARGARON.

This substance was discovered by M. Bussy in 1833.* He obtained it by distilling a mixture of four parts of margaric acid and one part of quicklime. A detailed account of it has been given in the *Chemistry of Vegetable Substances*, (p. 120.) It has been examined since with great accuracy by Messrs Redtenbacher and Varrentrapp. M. Redtenbacher found that it constituted one of the substances formed when stearic acid is subjected to distillation.† Varrentrapp repeated the experiments of Bussy, and purified the margaron first by digestion in potash, and then by repeated solutions in ether and crystallizations.‡

It is a white, pearly, scaly, crystallized substance, melting according to Redtenbacher, at 170°.5, according to Varrentrapp at 169°, according to Bussy at 170°. These slight differences probably are owing to errors in the thermometers used.

Margaron was analyzed by Bussy, Redtenbacher, and Varrentrapp. The result obtained was as follows:

	Bussy.	Redtenbacher.	Varrentrapp.	Mean.
Carbon,	82·22	82·483	81·62	82·108
Hydrogen,	13·51	13·863	13·80	13·724
Oxygen,	4·27	3·653	4·58	4·168
	100·00	100·000	100·00	100·000

These results approach each other very closely. As margaron neither combines with acids nor bases; and as it cannot be distilled over without decomposition, we cannot ascertain its atomic weight. But, if from the formula for hydrous margaric acid we subtract an atom of carbonic acid and an atom of water, the remainder will agree with the preceding analysis of margaron.

Hydrated margaric acid is	$C^{34} H^{34} O^4$
Subtract 1 atom carbonic acid,	$C \quad O^2$
And 1 atom water,	$H \quad O$
Remain,	$C^{33} H^{33} O$

* Ann. de Chim. et de Phys. liii. 398.

† Annalen der Pharm. xxxv. 57.

‡ Ibid. p. 80.

Now 33 atoms carbon,	= 24·75	giving per cent.	82·84
33 atoms hydrogen,	= 4·125	...	13·81
1 atom oxygen,	= 1·00	...	3·35
	29·875		100·00

This accords sufficiently with the mean of the preceding analyses to render it probable that margaron is formed by abstracting an atom of carbonic acid and an atom of water from hydrous margaric acid; and if this be so, then the constitution of margaron is $C^{33} H^{33} O = 29{\cdot}875$.

SECTION II.—OF ETHAL.

This oily-looking substance was discovered by Chevreul in 1818. He obtained it from the solid part of purified spermaceti, to which he gave the name of *cetin*. It was saponified and the soap decomposed by tartaric or phosphoric acid. The fatty matter which separates is a mixture of ethal with margaric and oleic acids. These acids are combined with barytes and the excess of barytes removed by boiling water. The whole is now digested in cold but very strong alcohol, which dissolves the ethal together with some margarate and oleate of barytes. When the alcohol is distilled off and the residue treated with absolute alcohol or ether, the ethal only is dissolved, and may be obtained pure by distilling off the solvent.

The properties of ethal, as determined by Chevreul, have been already detailed in the Chemistry of Inorganic Bodies, (Vol. ii. p. 332.)

In the Chemistry of Vegetable Bodies, (p. 321,) the subsequent analysis of ethal by Dumas and Peligot has been given. They obtained,

Carbon,	79.2
Hydrogen,	14·2
Oxygen,	6·6
	100·0

They consider its constitution to be,

16 atoms carbon,	= 12	or per cent.	79·34
17 atoms hydrogen,	= 2·125	...	14·05
1 atom oxygen,	= 1	...	6·61
	15·125		100·00

which obviously agrees very well with the analysis. These atomic numbers may be resolved into 4 (C^4 H^4) + H O.

Now, when ethal is mixed with dry phosphoric acid in powder and distilled, the acid retains an atom of water and a volatile oily body passes over, composed of,

Carbon, .	86 = 16 atoms =	12	or per cent.	85·71
Hydrogen,	14 = 16 atoms =	2	...	14·29
	100	14		100·00

Now the specific gravity of this liquid was found by them to be 7·846. But the specific gravity of

16 volumes carbon,	= 6·6666
16 volumes hydrogen,	= 1·1111
	7·7777

agreeing well with the specific gravity found. It appears from this that the volatile oily body thus obtained from ethal is a compound of sixteen volumes carbon and sixteen volumes hydrogen condensed into one volume. To this oily body Dumas and Peligot have given the name of *cetene.*

SECTION III.—OF CETENE.

This substance has been described in the Chemistry of Vegetable Bodies, (p. 322), to which the reader is referred.

There is every reason for believing that the oily liquid which M. Redtenbacher obtained along with margaron and margaric acid, when he distilled stearic acid, is identical with the cetene of Dumas and Peligot. He found it composed of

Carbon, .	83·92
Hydrogen, .	14·1

which approaches the result of Dumas and Peligot. The difference was doubtless owing to the presence of a little margaron, from which it was very difficult to free it.

SECTION IV.—OF CASTORIN.

Castor is a well known substance, which is obtained from the beaver. In each of the inguinal regions of that animal there are two bags, a large and a small. The large one contains the true castor; the small one a substance which has some resemblance to it, but which is in much less estimation.

Castor has a yellow colour, and when newly taken from the animal it is nearly fluid, but, by exposure to the atmosphere, it gradually hardens, becomes darker coloured, and assumes a resinous appearance. Its taste is bitter and acrid, and its smell strong and aromatic. In water it softens and tinges the liquid of a pale yellow colour.* The solution contains an alkali.

Castor was examined by Bouillon La Grange,* by Bizio,† and by Brandes,‡ and by various other chemists. Bizio first distinguished a substance which he extracted from it by the name of *castorin*. It had been already noticed by Fourcroy, Barneveld, and Bohn; but considered by them as *adipocire*. It may be extracted from castor by the following process:

Boil castor in six times its weight of alcohol of the specific gravity 0·85; filter and leave the liquid in an open glass till it is reduced to one-half by evaporation; draw off the liquid portion from the castorin deposited, and wash this last with cold alcohol, which partly removes the brown-coloured resinous matter. To remove this matter completely, digest the castorin with an aqueous solution of ammonia, potash, or soda; or treat its alcoholic solution with animal charcoal. Such is the process employed by Bizio.

Brande's process is somewhat different. He boiled castor with alcohol, and filtered it hot. On cooling, it deposited a little fatty matter. The alcoholic solution was then put into a retort, and the greatest part of the alcohol distilled off. The liquid portion in the retort was now separated from the castorin deposited. This last substance was purified by washing it in cold alcohol.

Castorin is white, and crystallizes from its solutions in fine four-sided transparent needles collected together in groups. It has a slight smell of castor, and a peculiar metallic taste. It does not alter vegetable colours. It is light and easily reduced to powder. When put into boiling water, it melts into an oil, which swims on the surface of the liquid, and which, after becoming solid on cooling, remains transparent. When boiled with water in a retort, it goes over in small quantities with the liquid, which is at first limpid; but after a certain time, deposites castorin. When heated *per se* in a retort, it melts, boils, and an orange-

* Jour. de Phys. xlii. † Brugn. Giorn. xvii. 174.
‡ Br. Arch. xvi. 281.

yellow oil distils over, which, on cooling, constitutes a soft matter, having a resinous aspect.

Castorin is inflammable, and burns without smoke or smell, leaving a quantity of charcoal behind it. It is insoluble in cold water; boiling water dissolves a small quantity, which in a few days is deposited in crystals. It dissolves with difficulty in alcohol, but the stronger that liquid is, the more of it does it dissolve. Alcohol of 0.860 dissolves only $\frac{1}{120}$th of its weight of castorin at the boiling temperature. It is more soluble in ether. The volatile oils while cold do not dissolve it. But oil of turpentine dissolves it with the assistance of heat, and becomes muddy on cooling. It may be melted with the fat oils.

Concentrated sulphuric acid dissolves it readily. The solution is yellow, and water throws down the castorin of a yellow colour.

Diluted sulphuric acid dissolves it when assisted by heat. The castorin is precipitated when the solution cools, or when the acid is saturated with ammonia. Cold nitric acid does not dissolve it; but this acid dissolves it while boiling hot, and the solution has a yellow colour. It becomes muddy on cooling, and the castorin is precipitated by the addition of water. When nitric acid is made to act long on castorin, it converts it into *castoric acid.*

Boiling acetic acid dissolves castorin abundantly; when the solution is concentrated by evaporation, the castorin is deposited in crystals. The dilute alkaline leys dissolve a little of it when assisted by heat, and on cooling the castorin is deposited unaltered. Concentrated solution of caustic potash dissolves it at a boiling temperature, and when the ley is diluted with water, the castorin precipitates unaltered.

SECTION V.—OF AMBREIN.

The substance called ambergris is found floating on the sea near the coasts of India, Africa, and Brazil, usually in small pieces, but sometimes in masses of 50 or 100 lbs. weight. Various opinions have been entertained respecting its origin. Some affirmed that it was the concrete juice of a tree;* others thought it a bitumen; others altered bees-wax.† But it is now considered as pretty well established that it is a concretion formed in the stomach or intestines of the *Physeter macrocephalus*, or spermaceti whale. This fact was first ascertained by the fishermen of New

* Phil. Trans. 1673, viii. 6113. † See Pomet on Drugs, ii. 46.

England about the year 1720. They found about 20 lbs. of ambergris in the intestines of one of these animals.* This account was confirmed in 1783 by Dr Schwediawer,† and in 1791 by Mr Champion.‡

Ambergris, when pure, is a light soft substance which floats in water. Its specific gravity, as determined by Brisson, varies from 0·78 to 0·92. Its colour is ash-gray, with brownish-yellow and white streaks. It has an agreeable smell, which improves by keeping. It is insipid to the taste.

Ambergris was subjected to a chemical examination by Bouillon Lagrange about the beginning of the present century;§ by Bucholz in 1810.‖ Pelletier and Caventou subjected it to a new examination in 1820,¶ and showed that it consisted chiefly of a peculiar fatty matter, which they distinguished by the name of *ambrein*; and in 1832 Pelletier subjected ambrein to a chemical analysis.**

Ambrein may be obtained by digesting ambergris in hot alcohol of the specific gravity 0·827. The alcohol, on cooling, deposites the ambrein in very bulky and irregular crystals, which still retain a considerable portion of alcohol. This may be got rid of, by subjecting the ambrein to pressure between folds of blotting-paper.

Ambrein thus purified is a white, brilliant, and insipid solid. It has an agreeable smell, which may be driven off by keeping the ambrein a long time in a state of fusion by means of a gentle heat; or by repeated solutions in alcohol and crystallizations.

According to Pelletier and Caventou, it melts, when heated, to 86°, and softens at 77°. When heated on platinum foil, it melts, smokes, and is volatilized, without leaving any residue. It is insoluble in water, but dissolves readily in alcohol and ether. When distilled *per se* in a retort, it becomes brown, but passes over into the receiver without having suffered any notable alteration, leaving in the retort a little charcoal. It dissolves also in volatile and fixed oils. Nitric acid converts it into a peculiar acid, which has been already described in a preceding chapter of this volume under the name of *ambreic acid*.

* Phil. Trans. 1724, xxxvii. 193, 256.
† Ibid. 1783, p. 226.
‡ Phil. Trans. 1791, p. 43.
§ Ann. de Chim. xlvii. 68.
‖ Ann. de Chim. lxxiii. 95.
¶ Jour. de Pharm. vi. 49.
** Ann. de Chim. et de Phys. li. 187.

Ambrein, like cholesterin, is incapable of being converted into soap, showing clearly that it does not possess acid properties.

Pelletier subjected ambrein to an ultimate analysis by means of oxide of copper, and obtained,

Carbon,	83·37
Hydrogen,	13·32
Oxygen,	3·31
	100·00

As we do not know any substance with which ambrein combines in definite proportions, we cannot determine its atomic weight. This puts it out of our power to state the number of atoms which enter into its composition. But the smallest number of atoms which correspond with the preceding analysis is the following:

33 atoms carbon,	= 24·75	or per cent.	83·20
32 atoms hydrogen,	= 4.	...	13·44
1 atom oxygen,	= 1·	...	3·36
	29·75		100·00

This would make the atomic weight 29·75. It is obvious, from the quantity of oxygen, that the number of atoms cannot be fewer than here stated; but, for any thing that appears, they may be double or triple that quantity.

SECTION VI.—OF CHOLESTERIN.

This substance was noticed by Gren in 1789, as constituting the greatest part of a gall-stone which he subjected to a chemical analysis.* He gave it the name of a *waxy-looking substance.* Chevreul afterwards examined its properties more in detail, and stated that he had discovered it as one of the constituents of *oils.* He made its distinctive characters known in a paper which was read to the French Institute in the year 1814. The same subject was again taken up by him in his *Recherches Chimiques sur les Corps Gras,* published in 1823.† In that work, Chevreul assures us, that cholesterin was first obtained by Poulletier de la Salle by treating gall-stones with boiling alcohol. I find this statement verified by Macquer, who, in the second edi-

* Beytr. z. d. Chem. Annalen, iv. 19. † Sur les Corps Gras, p. 155.

tion of his Dictionary of Chemistry, published in 1778, notices cholesterin as a singular substance, and gives some of its properties, and informs us, that it was discovered by the author of the French translation of the London Pharmacopœia.* This was Poulletier de la Salle. In 1834, Couerbe showed that it exists also as a constituent of the *brain* ; though between that in the brain and in human gall-stones there are some differences which we shall point out at the end of this section.

Cholesterin may be obtained in a state of great purity by digesting human gall-stones in boiling alcohol, drawing off the clear solution, and leaving it to cool. The cholesterin is deposited in beautiful crystalline plates. It may be obtained from bile by the following process :

Evaporate the bile to the consistence of a thick extract ; agitate this extract several times in succession with ether, till that liquid ceases to extract any thing from it. Mix all these etherial liquids, and draw off the greatest part of the ether by distillation. The residue, on cooling, deposites crystals of cholesterin, mixed with some oleic acid. This may be got rid of either by digesting the impure cholesterin with dilute caustic alkali, which dissolves the oleic acid, and leaves the cholesterin pure ; or, by dissolving the impure crystals in boiling alcohol, as the solution cools, the cholesterin is deposited in crystals, and in a state of purity.

Cholesterin crystallizes in beautiful white plates, having a pearly lustre. It has some resemblance to spermaceti, but is more beautiful. It has neither taste nor smell. It is lighter than water, and when heated to 278°, it melts into a liquid as colourless as water. On cooling, it concretes into a foliated crystalline mass, translucent, and capable of being reduced to powder. But the powder attaches itself strongly to every body with which it comes in contact. When distilled *per se* in a retort, (air being excluded,) it mostly passes over unaltered, and is deposited in crystalline plates. But if air have free access, the cholesterin undergoes decomposition, assumes a brown or yellow colour, and a considerable quantity of empyreumatic oil is formed, which holds a portion of cholesterin in solution. According to Kühn,† if we heat cholesterin in a glass-tube till a portion of it sublimes, and

* Macquer's Dict. i. 501.

† Diss. de Cholesterine. Leipsik, 1828.

then allow it to cool, the portion not sublimed remains in a liquid state, even though cooled down to zero.

Cholesterin does not act on vegetable blues; does not form a soap with potash; with sulphuric acid it strikes an orange-red colour.*

The crystals of cholesterin deposited from alcohol contain about 5·15 per cent. of water of crystallization, which may be driven off by heat. When heated on platinum foil, it catches fire and burns like wax. It is very little soluble in water. Cold alcohol dissolves very little; but the stronger the alcohol, the more it dissolves. According to Chevreul, boiling alcohol of 0·84 dissolves the ninth part of its weight of cholesterin; while boiling alcohol of 0·816 dissolves $\frac{1}{5.3}$. Pyroxylic spirit behaves almost exactly as alcohol. But a considerable portion of the cholesterin is retained in solution after the spirit cools. Ether, at 32°, dissolves $\frac{1}{12}$, at 59°, $\frac{1}{3.7}$, and at a boiling temperature, $\frac{1}{2.2}$ of its weight of cholesterin. It is very slightly soluble in oil of turpentine, but may be united to the fixed oils by fusion.

It does not dissolve in sulphuric acid, but gives the liquid a yellow colour. It then becomes viscid, and swims on the surface of the acid in the form of a pitchy mass, while at the same time sulphurous acid is evolved. The decomposition goes on still more rapidly when the acid is heated. Nitric acid converts it into cholesteric acid and artificial tannin.

Cholesterin was subjected to an ultimate analysis by Chevreul† and by Couerbe,‡ and by Pelletier,§ who found it composed of,

	Chevreul.	Couerbe.	Pelletier.
Carbon, -	85·095	84·895	83.37
Hydrogen, -	11·880	12·099	13·32
Oxygen, -	3·025	3·006	3·31
	100·000	100·000	100·00

The smallest number of atoms which corresponds with this analysis is the following:

38 atoms carbon,	= 28·5 or per cent.	85·07
32 atoms hydrogen,	= 4·0 ...	11·94
1 atom oxygen,	= 1·0 ...	2·99
	33·	100.00

* Chevreul; Jour. de Physiologie, iv. 257. † Sur les Corps Gras, p. 153.
‡ Ann. de Chim. et de Phys. lvi. 183. § Ibid. li. 188.

According to this statement, the atomic weight of cholesterin is 33·5. We have seen that the crystals are composed of,

Cholesterin,	94·85 or	67
Water,	5·15 or	3.636
	100·00	

Now 3·636 is very nearly the weight of 3 atoms of water. Hence it is not unlikely that the true atomic weight of cholesterin is 67, and that its constitution is $C^{76} H^{64} O^2 = 67$.

M. Couerbe found cholesterin in the human *brain*,* and doubtless it may be extracted from the brains of most of the Mammalia. The brain was digested four times successively in ether, till every thing soluble in that liquid was taken up. The residue was treated with boiling alcohol till every thing soluble in that liquid was abstracted. The alcohol on cooling deposited a white matter. This white matter being digested in cold ether a quantity of cholesterin is dissolved, which separates in crystals when the ether is evaporated.

The quantity of cholesterin in the brain is considerable. It possesses the same characters as that from biliary calculi, excepting that it does not melt till heated to 293°. It remains in a liquid state till cooled down to 239°, provided it be quite still, but the least agitation, that for instance caused by touching it with a hair, makes it immediately congeal into a crystalline solid. Couerbe found the ultimate constituents of cholesterin from biliary calculi, and from the brain the same. The cholesterin from the brain differs from that of biliary calculi in one remarkable circumstance. It dissolves better in alcohol, and furnishes a solution as it were unctuous. When filtered and allowed to cool it does not deposite crystals immediately. The crystallization begins after an interval of some time. The crystals are plates, often several inches long and beautiful, provided no *cerebrote* be present.

SECTION VII.—OF SEROLIN.

This substance was detected in the serum of blood by M. Boudet in 1833.† He obtained it by setting aside a hot alcoholic decoction of dried serum. As the alcohol cooled, a white matter, having a slightly pearly lustre, was deposited. It was *serolin*.

* Ann. de Chim. et de Phys. lvi. 180. † Jour. de Pharm. xix. 299.

It is composed of very minute white filaments, distinguishable only under the microscope. It melts, when heated, to 97°, has no acid reaction, and, like cholesterin, becomes red when placed in contact with concentrated sulphuric acid. It does not form an emulsion with cold water, and when the liquid is heated, the serolin floats on the surface under the form of a colourless oil. Sulphuric ether dissolves it readily even without the assistance of heat. Alcohol of 0·842 dissolves only a minute trace of it when boiling-hot, and it is not in the least soluble in cold alcohol. It was digested for six hours in potash ley, without being dissolved. Hence, like cholesterin, it seems incapable of forming soap. Acetic and muriatic acids do not act upon it whether they be cold or hot. Though long heated in nitric acid, it is not dissolved; but it becomes soluble in potash ley, which it colours brown.

When distilled, it gives out a very characteristic odour, emits ammoniacal vapour, and is partly volatilized.

SECTION VIII.—OF CANTHARIDIN.

This name has been given to the substance in *cantharides* or Spanish flies, (*Meloe vesicatorius, Lytta vesicatoria*, &c.) which occasions a blister when applied to the skin. Its properties were examined by Robiquet in 1810,* and more lately by L. Gmelin. Robiquet obtained it by the following process:

Cantharides were boiled in water till every thing soluble in that liquid was taken up. The aqueous solution was concentrated to the consistence of a thick syrup, which was repeatedly boiled in alcohol, till that liquid ceased to act upon it. The alcoholic solution was evaporated to dryness in a gentle heat. The residue was put into a phial with ether, and agitated for a considerable time. After some hours the ether assumed a yellow colour. It was then decanted off, and left to spontaneous evaporation in an open dish. As the ether evaporated, small crystalline plates were deposited mixed with a yellow matter. Alcohol took up the yellow matter, but left the plates. Being dried between folds of blotting-paper, these plates constituted *cantharidin* in a state of considerable purity.

Thus obtained, it is in small crystalline plates, resembling mica, which melt, when heated, into a yellow, oleaginous liquid. On cooling, it concretes into a crystalline solid. When heated more

* Ann. de Chim. lxxvi. 302.

strongly it is volatilized in a white smoke, which condenses into a white crystalline sublimate. The smallest particle of this matter is sufficient to raise a blister on the skin. Even the eyes, the nose, and the organs of respiration cannot be exposed to the vapour of it without hazard.

Cantharidin is neutral, neither reacting as an acid or base. It is insoluble in water, almost insoluble in cold alcohol, but soluble in that liquid when boiling-hot. It is very soluble in ether and in the fat oils. It was analyzed by M. Regnault;* 1060 parts gave 2298 of carbonic acid, and 576 of water. Hence the constituents are

Carbon,	59.00
Hydrogen,	6·04
Oxygen,	34·96
	100·00

He represents the constitution of cantharidin by the formula $C^{10} H^6 O^4$. If we calculate from this, we get

10 atoms carbon	= 7·5	or per cent. of	61·21
6 atoms hydrogen	= 0·75	...	6·13
4 atoms oxygen	= 4·	...	32·66
	12·25		100

There is always a deficiency of carbon in the ordinary analyses by Liebig's apparatus. This occasions a corresponding increase in the oxygen.

CLASS IV.

OF ANIMAL COLOURING MATTERS.

These have hitherto been very imperfectly investigated. Only a very few of the great number of colouring matters which occur in the animal kingdom can be noticed here; because they have not hitherto attracted the attention of chemists.

* Ann der Pharm. xxix. 314.

CHAPTER I.

OF CARMIN.

Cochineal (*Coccus cacti*) is an insect which inhabits different species of *cactus*,* as the *coccinellifer*, *opuntia*, *turia*, &c. These plants are cultivated in Mexico and some other parts of America for the nourishment of the insect.

The females are stationary upon the plant. They are collected, killed by heat, and then dried. They occur in commerce in the state of small dark-brown grains; and are employed in dyeing *scarlet*, and in making a beautiful red lake used as a colour by painters.

Cochineal was first examined by Dr John 1813.† He made a chemical analysis of the insect, extracted the colouring matter, and described its characters under the name of *cochenillin*. In 1818, an elaborate examination of cochineal and of its colouring matter under the name of *carmin*, was published by Pelletier and Caventou,‡ and in 1832 the subject was farther prosecuted by Pelletier, who made a chemical analysis of *carmin* and determined its constitution.§

Carmin may be obtained from the cochineal insect in the following manner: Digest the cochineal insect in alcohol as long as it communicates a red colour to that liquid. When these solutions are left to spontaneous evaporation they let fall a crystalline matter of a fine red colour. This is *carmin*, but not in a state of purity. Dissolve these crystals in strong alcohol, and mix the solution with its own bulk of ether. The liquid becomes muddy, and after an interval of some days the *carmin* is deposited at the bottom of the vessel, forming a beautiful purplish red crust.

Carmin thus obtained has a fine purple red colour. It adheres strongly to the sides of the vessel in which it is deposited. It has a granular appearance, as if it were composed of crystals.

* A detailed account of this insect, of the wild cactus, and of the mode of rearing these insects, and preparing them for dye stuff, may be found in Bancroft's Researches concerning the Philosophy of Permanent Colours, i. 236.

† Chemische Untersuchungen, iii. 210.

‡ Ann. de Chim. et de Phys. viii. 250. § Ibid. li. 194.

It is not altered by exposure to the air, nor does it absorb any sensible quantity of moisture. When heated to 122° it melts. If the heat be increased it swells up, and is decomposed, yielding carburetted hydrogen, a great deal of oil and a little water, having a slightly acid taste. It gives no trace of ammonia; yet, according to the analysis of Pelletier and Caventou, azote constitutes one of its constituents, though its quantity is small.

Carmin is very soluble in water. The solution may be concentrated by evaporation to the consistence of a syrup; but no crystals are deposited. The aqueous solution has a fine carmine red colour. A very small quantity of carmin communicates its colour to a great deal of water. It is soluble also in alcohol; but the stronger the alcohol, the worse a solvent it becomes. It is insoluble in ether. The weak acids dissolve it, probably in consequence of the great quantity of water which they contain. No acid precipitates it when pure; but they almost all throw it down when it is in combination with the peculiar animal matter of the cochineal. All the acids, however, induce a sensible change upon the aqueous solution of carmin. They cause it, in the first place, to assume a lively red colour, which gradually acquires a yellowish tinge, and at last becomes quite yellow. When the acids are not very concentrated, the carmin is not altered in its nature, for when we saturate the acid, the solution assumes its original colour.

Concentrated sulphuric acid destroys and chars carmin. Muriatic acid decomposes it without charring, and converts it into a bitter tasted substance, which has no resemblance to the original colouring matter. Nitric acid decomposes it with still greater rapidity. Some needle-form crystals are formed similar in appearance to oxalic acid; but they do not precipitate lime-water, even when mixed with ammonia.

Chlorine acts with energy on carmin, giving it at first a yellow colour, and afterwards destroying the colour altogether. Chlorine causes no precipitation in an aqueous solution of carmin, provided the solution be pure. It is therefore a useful reagent to enable us to discover the presence of an animal matter in the solution of carmin. Iodine acts precisely as chlorine, but with less rapidity.

The alkalies, when poured into a solution of carmin, give it a violet colour. If the alkali be saturated immediately, the origi-

nal colour of the solution reappears, but if the action of the alkali be prolonged, or if it be increased by the application of heat, the violet colour is destroyed, and the liquid becomes first red and then yellow.

Lime-water occasions a violet-coloured precipitate when dropt into the aqueous solution of carmin. Barytes and strontian cause no precipitate, but produce the same change of colour as the alkalies. Alumina has a very strong affinity for carmin. When newly precipitated alumina is put into an aqueous solution of carmin, the liquid is deprived of its colour, and the alumina converted into a beautiful *lake*. If a few drops of acid be added to the aqueous solution before introducing the alumina, the lake obtained has a fine red colour as before, but it becomes violet on the application of the least heat. The same effect is produced if we add to the liquid a few grains of an aluminous salt.

Most of the saline solutions alter the colour of the aqueous solution of carmin, but few of them are capable of throwing down a precipitate from it. Solutions of gold merely alter the colour; nitrate of silver occasions no change whatever; the soluble salts of lead render the colour violet; and acetate of lead occasions an abundant violet precipitate. By decomposing this precipitate by means of a current of sulphuretted hydrogen, we may obtain the carmin dissolved in water in a state of purity. Protonitrate of mercury throws down a violet precipitate. Pernitrate of mercury does not act so powerfully, and the colour of the precipitate is scarlet. Corrosive sublimate produces no effect whatever.

Neither salts of copper nor of iron produce any precipitate; but the former change the colour of the liquid to violet, the latter to brown. Protochloride of tin throws down a copious violet precipitate; while the perchloride changes the colour to scarlet, but precipitates nothing. When gelatinous alumina is added to the mixture, we obtain a fine red precipitate, which is not altered by boiling. None of the aluminous salts occasion a precipitate; but they change the colour to carmin. The salts of potash, soda, and ammonia, change the colour of the liquid to carmin red.

From the action of the different salts on carmin, Pelletier and Caventou have drawn as a conclusion, that the metals susceptible of different degrees of oxydizement act like acids on the colouring matter when at a maximum of oxidation, but like alkalies when at a minimum or medium degree; and that this alkaline

influence may be exercised in the midst of an acid when the oxides in question are capable of forming an insoluble precipitate with the carmin.

Tannin and astringent principles in general do not precipitate carmin.

Pelletier and Caventou analyzed carmin in 1818 by means of black oxide of copper, without obtaining any azotic gas. But in a new analysis published by them in 1832, they state the amount of azote in carmin to be 3·56 per cent. But no particulars respecting the mode of the analysis or the substances obtained are stated. The bare centesimal result is given. So that we have no means of judging the degree of accuracy which was obtained. The following table exhibits their analysis:

Carbon,	49·33	or 32 atoms =	24	or per cent. 49·00
Hydrogen,	6·66	or 24 atoms =	3	... 6·63
Azote,	3·56	or 1 atom =	1·75	... 3·57
Oxygen,	40·45	or 20 atoms =	20·00	... 40·80
	100·00		48·75	100·

The carmin subjected to this analysis was previously dried *in vacuo* by a heat not specified. Pelletier and Caventou think it not unlikely that it still retained a portion of water.

In the year 1819, M. Lassaigne examined another species of *Coccus*, the *Coccus ilicis*, or *kermes*, which is common in the south of Europe, and which had been employed as a red dye before the introduction of cochineal after the discovery of America. From his experiments it appears that kermes in its nature bears a close resemblance to cochineal, and that it also contains a considerable proportion of *carmin*, identical in its nature with that from the *Coccus cacti*.*

CHAPTER II.

OF SERICIN, OR THE COLOURING MATTER OF SILK.

It is universally known that raw silk is a very fine thread spun by the silk-worm (*Bombyx mori*,) and in which it envelopes itself while in the chrysalis state. In China there is a silk-worm which

* Jour. de Pharmacie, viii. 435.

spins a thread of the most dazzling whiteness. But the colour of raw silk from India, Italy, and France is yellow. Some experiments on this colouring matter were made by Roard in 1807.* According to him it is a resinous substance, almost solid at the temperature of 59°, but quite fluid at 86°. Its colour is reddish-brown while in lumps, but a fine greenish-yellow when in a state of division. Silk contains from $\frac{1}{33}$th to $\frac{1}{60}$th part of it. Its smell is strong, proceeding from a volatile oil which it contains. Light bleaches it completely in a few days, when concentrated solutions of it are exposed to its action. It is insoluble in water, but very soluble in alcohol. The fixed alkaline leys, especially ammonia, dissolve a little of it while cold, and the action is not much increased by heat; while soap, which has little action while cold, is rather a powerful solvent of it at the temperature of boiling water. Concentrated sulphuric and muriatic acids char it immediately. Sulphurous acid partially bleaches it. Chlorine bleaches it instantly, converting it into a solid matter like wax.

According to Mulder † the colouring matter of yellow silk has a fine red colour. He obtained it in the following manner:—The alcoholic tincture of raw yellow silk is concentrated by distillation to a small quantity; flocks of *cerin* are deposited. The residual liquid being now evaporated, the colouring matter remains mixed with fat and resin. From these substances it is freed by digestion in a solution of caustic potash. This solution must not be too strong, otherwise the fine red of the colouring matter is rendered dark.

This colouring matter is insoluble in water; but very soluble in alcohol, ether, fat and volatile oils. When placed in contact with chlorine or sulphurous acid, it becomes light yellow; indeed, almost white.

The quantity of colouring matter in raw yellow silk is, according to Mulder, about $\frac{1}{2000}$th part of the silk.

* Ann. de Chimie, lxv. 61. † Poggendorf's Annalen, xxxvii. 610.

CHAPTER III.

OF CANCRIN, OR THE COLOURING MATTER OF CRABS.

It is well known that the *crusts* which cover the different species of *Cancer*, as the *gammarus* (or *lobster*), the *astacus* (or *craw-fish*), &c. are black, or nearly so, but become of a fine red colour when boiled. It is evident from this that they contain a peculiar colouring matter.

Dr John made a chemical examination of the crust of the *Cancer astacus* in 1811.* He notices some of the characters of the colouring matter; but does not seem to have made any attempt to obtain it in a separate state. Lassaigne, in 1820, succeeded in isolating it, and made some experiments on it. † The investigation was carried somewhat farther in 1821 by M. Macaire, who found two different colouring matters in these crusts ‡

The colouring matter of these crusts is analogous to suet. In the natural state its colour is dark bluish-green. When heated to 158° it becomes red, and then has some resemblance to the beak of the duck. It is contained partly in the shell, and partly in the greenish membrane immediately under the shell. Some of it is also to be found in another membrane situated immediately below the green one, and from which it may be separated by maceration in water. But in this second membrane, the colouring matter is already red. Lassaigne obtained the colouring matter by digesting the clean shell in alcohol till that liquid ceased to extract any thing more. The alcoholic solution is red. When it is evaporated to dryness there remains a solid red matter, similar to suet, which, after having been washed in hot water, may be kept without undergoing any alteration. It is insoluble in water; but very soluble in alcohol and ether. The alcoholic solution has a scarlet colour, and is not precipitated by water. It is soluble by the assistance of heat in melted tallow, and in the volatile oils. It is stated by Macaire not to be soluble in the fixed oils.

It dissolves readily in dilute sulphuric acid, but is decomposed

* Chemische Untersuchungen, ii. 49.

† Jour de Pharmacie, vi. 174

‡ Bibl. Univer., July 1821, or Schweigger's Journal, xxxiii. 257.

by that acid when in a concentrated state. Nitric acid converts it into a bitter tasted matter. When the alcoholic solution is mixed with sulphuric or nitric acid, it becomes green, and the red colour is not restored by saturating the acid with an alkali. Caustic potash dissolves it, assuming a red colour. From this solution it is precipitated by the acids, without having been acidified. The alcoholic solution loses its colour when alum is added to it. If we add ammonia we obtain the colouring matter united to alumina. The alcoholic solution is precipitated by acetate of lead. The compound of the colouring matter and oxide of lead is violet. The salts of iron, tin, copper, and mercury have no action on it.

The deep green shell of the *canfri* is reddened by acids, alkalies, by some salts, by putrefaction; by the action of air and oxygen, but it is not reddened by carbonic acid nor by hydrogen. Chlorine gas bleaches it. According to the analysis of Gœbel it is composed of,

Carbon,	68·18	or 16 atoms carbon	= 12	or per cent.	68.08
Hydrogen,	9·24	or 13 atoms hydrogen	= 1·625		9·22
Oxygen,	22·58	or 4 atoms oxygen	= 4·		22·70
	100·00*		17·625		100·

CHAPTER IV.

OF PERISTERIN OR THE COLOURING MATTER OF PIGEON'S FEET.

This red colouring matter was examined by Gœbel, who found it analogous to that of the craw-fish. It is easily separated by digesting the pigeon's foot in water. The external cuticle by this process is easily separated, so that the red pigment is quite exposed, and may be easily separated by a fine knife.

It is easily soluble in absolute ether and alcohol, forming a fine carmine red solution. When the liquid is evaporated the colouring matter remains as a fine shining red mass, having the consistence of tallow. It is insoluble in water. On hot water it swims in red drops; but concretes into a solid mass when the liquid cools. It dissolves in caustic potash. The solution may be

* Schweigger's Journ. xxxix. 429.

diluted with water, and the colouring matter is precipitated unaltered by acids. Acetic acid does not dissolve it. Sulphuric and nitric acids decompose it. It is soluble in volatile oils; and all its solutions have a fine red colour.

Its taste and smell are weak and mouldy, somewhat similar to that of fat. It does not alter the colour of vegetable blues. According to the analysis of Gœbel it is composed of,

Carbon,	.	69·02
Hydrogen,		8·74
Oxygen,	.	22·24
		100·00*

As we are ignorant of the atomic weight of this substance we cannot deduce its constitution from this analysis. But the smallest number of atoms of each constituent deducible from it are the following:

4 atoms carbon,	= 3·	or per cent.	68·58
3 atoms hydrogen,	= 0·375	.	8·57
1 atom oxygen,	= 1·	.	22·85
	4·375		100·00

CHAPTER V.

OF ANSERIN, OR THE COLOURING MATTER OF GOOSE FOOT.

The pigment on the feet and bills of the goose has a yellow colour, and possesses all the chemical characters of the colouring matter of the craw-fish and pigeon's foot. At the ordinary temperature of the atmosphere it is liquid and resembles oil, but at 45½°, it assumes the consistence of tallow. Its constituents, as determined by Gœbel, are,

Carbon,	.	65·53
Hydrogen,	.	9.22
Oxygen,	.	25.25
		100·00†

The atomic weight being unknown we cannot deduce the con-

* Schweigger's Journ. xxxix. 426. † Ibid. xxxix. 430.

stitution of the pigment from this analysis. But the smallest number of atoms which corresponds with the preceding analysis is the following:

10 atoms carbon,	. = 7·5	or per cent.	64·52
9 atoms hydrogen,	= 1·125	.	9·68
3 atoms oxygen,	. = 3·000	.	25.80
	11·625		100·00

CHAPTER VI.

COLOURING MATTER OF THE ANCIENT PURPLE DYE.

The most celebrated and precious of all the ancient dyes was the *purple*. The method of dyeing which was monopolized by the Tyrian dyers, who seem to have been acquainted with it at a very early period. The dye stuff was a white clammy liquor, obtained from a variety of univalve shells found on the coast of the Mediterranean. Pliny divides these shells into two genera, which he distinguishes by the names of *Buccinum* and *Purpura*.* About two drops of the liquid was obtained from each fish, by opening a reservoir placed in the throat. To avoid the trouble of extracting it from every individual fish, they were often bruised in a mortar. The liquor when extracted was mixed with salt to prevent putrefaction. It was then diluted with five or six times its weight of water, and kept moderately hot in leaden or tin vessels for the space of ten days, during which the liquor was often skimmed to separate impurities. After this the wool, previously washed, was immersed and kept therein for five hours. It was then taken out, carded. and immersed again, and kept in the liquid till all the colouring matter was extracted. Pliny informs us that the Tyrians first dyed their wool in the liquor of the *Purpura* and afterwards in that of the *Buccinum*.

Another mode of preserving the purple dye was by covering it with honey. Plutarch, in his Life of Alexander the Great, informs us, that there was found in the King of Persia's palace at Susa, five thousand talents of the *purple of Hermione*, which, though it had been laid up one hundred and ninety years, retain-

* Plinii, lib. ix. c. 36.

ed its first freshness and beauty. The reason assigned for this is, that the purple wool was combed with honey, and the white with white oil.*

The wool thus dyed was so costly that, in the time of Augustus, each pound of it sold for 1000 Roman denarii, (about L. 36, Sterling).

The art of dyeing this colour came at last to be practised only by a few individuals, maintained by the emperors for that purpose. It was interrupted about the beginning of the twelfth century, and all knowledge of it was lost. But in the year 1683, Mr Cole of Bristol, being told that a person at a sea-port in Ireland gained a living by marking linen with a red coloured dye stuff, was induced to make inquiry into his mode of proceeding. He found that the individual in question made use of a white liquor in the head of the *Buccinum lapillus* of Linnæus; a shell very common on our coasts.

Mr Cole procured this liquor from the fish, and stained linen with it. When exposed to the light of the sun the stain became first green, then blue, and finally a purple red.†

These experiments of Cole were afterwards repeated successfully by M. Jussieu, M. Reaumur, and M. Duhamel. They observed the same succession of colours. And they mention also a fetid smell like a mixture of garlic and assafœtida, given out while it was changing its colours. This smell had been also noticed by Cole. As no experiments on this curious liquid have been made by modern chemists, we are still ignorant of its nature and properties. I have mentioned it here merely to draw the attention of such chemists as, living upon the sea-coast, may have it in their power to procure the shell fish that yield it.

CLASS V.

OF ANIMAL AMIDES.

The substances included under this name constitute a very important portion of the materials of which animal bodies are composed. They are still so imperfectly known that we do not

* Langhorne's Plutarch, ix. 373.

† Phil. Trans. xv. 1278.

know whether they ought to be placed among animal acids or bases, or whether they are not rather indifferent substances. The last supposition accords best with the present state of our knowledge. They have a strong analogy to the *amides* from the vegetable kingdom; the account of which will be found in the *Chemistry of Vegetable Bodies*, p. 590. For this reason they have been placed together under that provisional denomination. They may be arranged under the following heads:

I. Protein.
   (1.) Albumen.
   (2.) Albumen from silk.
   (3.) Casein.
   (4.) Fibrin of blood.
   (5.) Fibrin of silk.
   (6.) Ricotin.

II. Gelatin,
   (1.) Collin.
   (2.) Chondrin.
   (3.) Gelatin from silk.

III. Hematosin

IV. Spermatin.

V. Salivin.

VI. Pepsin.

VII. Pancreatin.

These will be the subject of the seven following chapters.

CHAPTER I.

OF PROTEIN.

THIS name was given by Mulder to a substance which constitutes the bases of albumen, fibrin, flesh, casein, and probably of other animal tissues.* To obtain it, albumen from eggs or blood may be taken and digested in water, alcohol, and ether, till every thing soluble in these liquids has been removed. It is then treated with dilute muriatic acid, which removes the insoluble earthy salts, especially phosphate of lime. It is then to be dissolved in a moderately strong alkaline ley, and the solution must be heated to 122°, by which a little phosphate of potash and sulphuret of potassium are formed, originating from sulphur and phosphorus existing in the albumen in an unoxydized state. The protein thus treated is precipitated from its alkaline solu-

* So named from πρωτευω, I am first.

tion by acetic acid, added only to a very small excess, because too much would again dissolve the protein. The gelatinous precipitate is collected on a filter, and washed till every trace of acetate of potash is removed.

Protein thus purified constitutes gelatinous, translucent, greyish flocks which, when dried, assume a yellowish colour, and become hard and brittle, and easily pulverized. The powder is amber yellow, destitute of smell and taste, absorbs moisture from the atmosphere; which it again loses when heated to 212°. When heated, it undergoes decomposition before it melts. It swells up, gives out empyreumatic oil, ammoniacal water, and inflammable gas, and leaves a porous charcoal, which burns readily in the air without leaving any residue.

Protein sinks in water, and when left in that liquid, softens and swells, and assumes the original appearance which it had before it was dried. It is insoluble in water, alcohol, ether, and volatile oils. When boiled in water, it is partly dissolved, but the process is so slow, that after sixty hours boiling, most of the protein still remains unacted on. When the dissolved portion is evaporated, the matter remaining is translucent and yellow, and consists of two substances, one of which dissolves in alcohol, and the other not.

Protein combines both with acids and bases. It dissolves in all very dilute acids, and forms with them a kind of neutral compound, which is insoluble or difficultly soluble when there is an excess of acid present. Hence, if to a solution of protein sulphuric, nitric, phosphoric, or muriatic acid be added, the protein precipitates in combination with the acid added. And when the excess of acid is washed away, the precipitate again dissolves. Acetic acid and phosphoric acid constitute an exception, as they dissolve protein even when added in excess. When treated with them in a concentrated state, the protein first gelatinizes, and then dissolves. From the solution in acetic acid protein is precipitated by prussiate of potash, by tannin, and by an alkali.

The action of the strong acids produces alterations on protein. Concentrated muriatic acid, when air is excluded, gives a yellow solution, which becomes brown when oxygen gas is admitted. When the muriatic acid is allowed to act upon protein in an open vessel, the colour of the solution gradually deepens to indigo blue. When heat is applied, the liquid becomes black,

containing humin and sal-ammoniac, while an altered muriate of protein is deposited.

In concentrated sulphuric acid, protein swells into a jelly. When this jelly is cut into pieces, and put into cold water, that liquid removes the excess of acid, and the mass shrivels up into a white sulphate of protein, which is insoluble in water. This is the substance to which Mulder has given the name of *sulpho-proteic acid*. Its characters will be given afterwards. When protein is boiled with dilute sulphuric acid, it becomes purple-coloured.

Protein combines with alkalies and bases. With the alkalies and alkaline earths, it forms compounds soluble in water, from which it may be precipitated by the addition of alcohol. Its compounds, with the earths and metallic oxides, are insoluble.

Mulder analyzed three specimens of protein, the first obtained from fibrin, the second from albumen of eggs, and the third from albumen of serum of blood.* Dr Scherer analyzed also three specimens, the first from the crystalline lens of the eye, the second from albumen, and the third from fibrin.† The following table exhibits the results of these analyses:

	Mulder.			Scherer.			Mean.
	1.	2.	3.	1.	2.	3.	
Carbon,	54·94	54·93	55·40	55·300	55·160	54·848	55·096
Hydrogen,	6·95	7·07	7·16	6.940	7·055	6·959	7·022
Azote,	15·83	15·83	16·00	16·216	15·966	15·847	15·948
Oxygen,	22·29	22·17	20·34	21·544	21·819	22·346	21·752
	100·01	100·	98·90	100·	100·	100·	

Mulder represents the constitution of protein by the formula, $C^{40} H^{31} Az^{5} O^{12} = 54{\cdot}625$. If we calculate from this formula, we get

40 atoms carbon,	= 30·	or per cent.	54·93
31 atoms hydrogen,	= 3·875	...	7·09
5 atoms azote,	= 8·750	...	16·02
12 atoms oxygen,	= 12·000	...	21·96
	54·625		100·00

Numbers which almost coincide with the mean of the six analy-

* Ann. der Pharm. xxviii. 74. † Ibid. xl. 43.

ses. Scherer represents the constitution of protein by the formula $C^{48} H^{36} Az^{6} O^{14} = 65$. This formula gives,

48 atoms carbon,	= 36·	or per cent.	55·38
36 atoms hydrogen,	= 4·5	...	6·92
6 atoms azote,	= 10·5	...	16·16
14 atoms oxygen,	= 14·0	...	25·54
	65·0		100·00

This formula also comes very near the experimental quantity, showing how difficult it is to determine by calculation the constitution of such complicated compounds.

Protein has the property of combining with sulphuric acid, and of forming an acid to which Mulder has given the name of *sulpho-proteic acid.*

To prepare it, he mixed purified *casein* with concentrated sulphuric acid.* The solution was treated with ammonia, the excess of which was driven off by evaporation. Nitrate of silver dropt into the liquid gave a precipitate of sulpho-proteate of silver, which was washed and dried at 266°. He prepared another sulpho-proteate of silver by treating albumen of eggs in the same manner. 487 of the salt from casein gave 739 carbonic acid and 231 water: 120 parts gave 22 of metallic silver, and 760 gave 140 of sulphate of barytes. Hence the constituents in 100 parts must be,

Carbon,	41·36
Hydrogen,	5·27
Sulphuric acid,	6·35
Oxide of silver,	19·68
	72·66

What is wanting to make up the hundred parts must be azote and oxygen. But protein contains five atoms of azote and twelve atoms of oxygen. Hence the azote in 100 parts of the salt must weigh 14·08, and of consequence the oxygen must be 13·26; 477 of the salt containing the albumen gave 647 of carbonic acid, and 200 water. Hence 100 parts contain,

Carbon,	37·08
Hydrogen,	4·66

* Ann. der Pharm. xxxi. 127.

According to these imperfect analyses, the two salts consist of,

	From Casein.	From Albumen.
Carbon,	41·36	37·08
Hydrogen,	5·27	4·66
Azote,	14·08	
Oxygen,	13·26	
Sulphuric acid,	6·35	
Oxide of silver,	19·68	
	100·00	

Mulder considers the salt as composed of,

1 atom protein,	$C^{40} H^{31} Az^{5} O^{12}$
1 atom sulphuric acid,	SO^{3}
1 atom oxide of silver,	Ag O

He prepared sulpho-proteate of copper, and subjected it to analysis. Its constituents were,

Carbon,	32·17
Hydrogen,	4·58
Azote,	9·87
Oxygen,	16·85
Sulphuric acid,	11·68
Oxide of copper,	25·85
	101·00

He considers it as composed of

1 atom protein,	$C^{40} H^{31} Az^{5} O^{12}$
2 atoms sulphuric acid,	$2 (SO^{3})$
5 atoms oxide of copper,	5 (Cu O)

It is, in his own opinion, $(C^{40} H^{31} Az^{5} O^{12} + SO^{3}) + (2 \text{ Cu O} + SO^{3}) + (3 \text{ CuO} + 3 \text{ Aq})$.

I think it unnecessary to enter into any examination of these results, because the conclusions are obviously conjectural.

Tannate of Protein.—When albumen is mixed with water and the liquid passed through a filter, if we mix it with a solution of pure tannin, a white flocky precipitate falls, which is difficult to wash. When dried at 266° it still retains its white colour, and the tannin is unaltered, if the drying be cautiously conducted. It was subjected to analysis by Mulder.* It contained two per

* Ann. der Pharm. xxxi. p. 129.

cent. of a calcareous salt. He endeavoured to get a purer tannate by precipitating a solution of protein in acetic acid by tannin. 596 parts of this last salt gave 1154 of carbonic acid, and 290 of water. The volumes of carbonic acid and azotic gases were to each other as 58 to 5. Hence the constituents were,

Carbon,	52·80
Hydrogen,	5·41
Azote, .	10·87
Oxygen,	30·92
	100·00

He represents the composition of the salt by the formula,

$C^{58}\ H^{38}\ Az^{5}\ O^{23}$ resolvable into

1 atom protein,	$C^{40}\ H^{31}\ Az^{5}\ O^{12}$.
1 atom tannin,	$C^{18}\ H^{5}\ O^{9}$
2 atoms water, .	$H^{2}\ O^{2}$
	$C^{58}\ H^{38}\ Az^{5}\ O^{23}$

Protein-oxide of Lead.—When a solution of protein in acetic acid is mixed with a lead salt, a precipitate falls, composed of 10 atoms protein and 1 atom oxide of lead. If there be a great excess of acetic acid, the precipitate is composed of 5 atoms protein and 1 atom oxide of lead.*

Sulpho-bi-proteic Acid.—If we dissolve albumen in acetic acid, and add dilute sulphuric acid, we obtain a flocky precipitate, which may be washed with alcohol. When dried at 266° it is a compound of protein and sulphuric acid in definite proportions. It was analyzed by Mulder. 132 parts of it gave 16 of sulphate of barytes. Hence 100 parts contain 4·18 of sulphuric acid. 51 parts gave 95·2 of carbonic acid, and 31 of water. Hence it contained,

Carbon, . .	50·90
Hydrogen, .	6·74
Azote, . .	15·03
Oxygen, . .	23·15
Sulphuric acid, .	4·18
	100·00

The azote was not determined; but calculated on the supposition

* Ann der Pharm. xxxi. p. 131.

that it amounted to 20 atoms. He represents its constitution by the formula $C^{80}\ H^{64}\ Az^{10}\ O^{26} + SO^{3}$. Calculating from it we get,

80 carbon,	$= 60$	or per cent.	51·51
64 hydrogen,	$= 8$	...	6·86
10 azote,	$= 17·5$	...	15·03
26 oxygen,	$= 26$	...	22·31
1 sulphuric acid,	$= 5$	...	4·29
	116·5		100.

Mulder considers the precipitate as composed of

2 atoms protein,	$C^{80}\ H^{62}\ Az^{10}\ O^{24}$
2 atoms water,	$H^{2}\ O^{2}$
1 atom sulphuric acid,	SO^{3}



$C^{80}\ H^{64}\ Az^{10}\ O^{26}\ SO^{3}$

Chloro-bi-proteic Acid.—This acid may be formed in the same way as the last. It is composed of 2 atoms protein, 2 atoms water + 1 atom muriatic acid.

Action of Chlorine on Protein.—Mulder has made some experiments on the action of chlorine on protein.* When a current of dry chlorine is passed over protein it is absorbed, but the protein is not decomposed. The compound formed is a compound of 1 atom protein and 1 atom of chlorous acid. Hence its formula is $C^{40}\ H^{31}\ Az^{5}\ O^{12} + ClO^{3}$. This compound is easily washed and obtained in a state of purity.

To form it albumen was dissolved in water, and the liquid filtered. This solution being treated with chlorine no gas was evolved, but white flocks almost immediately appeared. They increased in number. In a few hours the action was at an end. The precipitate, which smelt of chlorous acid, was collected on a filter and washed. The washing was continued till the water nearly ceased to be acted on by nitrate of silver. But, as the precipitate is not altogether insoluble in water, the process must not be continued too long. The precipitate thus washed was pressed between folds of filtering-paper, and dried at 176°. It has a white colour with a tint of straw-yellow. It was finally dried at 212°. When heated on platinum foil it melted, gave out gas, swelled and burnt all away, without leaving any residue. During its

* Ann. der Pharm. xxxvi. 68.

combustion it gave out a smell analogous to saffron. The combustion was very slow. It was subjected to an ultimate analysis by Mulder. 527 parts of it gave 927 of carbonic acid, and 293 of water. 2750 parts of it gave 756 of chloride of silver. Hence 100 would have given 27·49 of chloride of silver = 6·87 chlorine = 11·62 chlorous acid. The azotic gas was determined by measurement, and was one-eighth part of the bulk of the carbonic acid gas. Hence the constituents are

Carbon,	47·97
Hydrogen,	6·18
Azote,	14·10
Oxygen,	20·13
Chlorous acid,	11·62
	100·00

He gives as the formula for its composition $C^{40}\ H^{31}\ Az^{5}\ O^{12} + ClO^{3}$; that is to say, an atom of protein and an atom of chlorous acid united together. Doubtless the oxygen of the chlorous acid was obtained by the decomposition of three atoms of water.

When casein or fibrin was used instead of albumen, the compounds formed were identical; showing that the protein from albumen is isomeric with that from casein and fibrin.

The liquid from which the chloro-proteic acid had been precipitated by chlorine was transparent, very acid, and smelled of chlorous acid, though very little of that acid was present. When saturated with ammonia only two or three bubbles of azotic gas were extricated. Being evaporated to dryness, it left a great quantity of sal-ammoniac. We see from this that the water had been decomposed by the action of the chlorine; the chlorous acid united to the protein, but the muriatic acid remained dissolved in the water.

Dry chloro-proteic acid is a straw-yellow powder with a fatty feel. It is insoluble in alcohol and ether, and almost insoluble in water. In concentrated sulphuric acid it dissolves without communicating any colour. When water is added to the solution white flocks precipitate. When nitric acid is made to act upon it for several days at the common temperature of the atmosphere it gradually dissolves it, and converts it to *xanthoproteic acid.* When acted on by muriatic acid cold, it is not converted into *humin* as is the case with protein. It forms in it a colourless solution.

Chloroproteic acid is soluble in barytes water. If no heat be applied to the solution, carbonic acid may be passed through it. If we then heat and filter it we have a colourless solution, which, when evaporated, leaves a residue containing organic matter, barytes, and chlorine. Chloroproteic acid is soluble in ammonia with the evolution of much azotic gas. When the solution is evaporated we obtain a residue soluble in hot water. Alcohol throws down from this solution a new organic matter, while sal-ammoniac remains in solution. Mulder distinguishes this new organic matter by the name of *Oxyprotein.*

It is a yellow powder which must be treated with boiling alcohol to free it from the ammoniacal salt: and it always retains a small quantity of chlorine. Mulder dried it at 212°, and subjected it to an ultimate analysis. 603 parts of it gave 1108 of carbonic acid, and 358 water. 100 parts gave 15·12 of azote. Hence the constituents are,

Carbon,	50·16
Hydrogen,	6.50
Azote,	15.12
Oxygen,	28·22
	100·00

He represents the constitution by the formula $C^{40}\ H^{31}\ Az^{5}\ O^{15} + HO$. It is therefore a hydrated oxide of protein; or protein combined with three atoms water. The chloroproteates when they lose their chlorine by the action of ammonia do not lose the oxygen of the chlorous acid, which forms with the protein a new body.

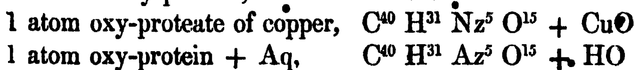
Oxy-protein constitutes a brittle and easily pulverized mass, having an amber colour. It is heavier than water and soluble in that liquid. It is scarcely soluble in alcohol and quite insoluble in ether. It dissolves in dilute sulphuric acid at a boiling temperature. Strong boiling muriatic acid dissolves it also without becoming coloured. By nitric acid it is converted into xanthoproteic acid. It is soluble in potash, soda, ammonia, and barytes water. The aqueous solution is not precipitated by prussic acid. Sulphuric acid throws down a white precipitate, which dissolves when the liqour is heated, and again falls when it cools. With infusion of nutgalls it gives an abundant precipitate. Ni-

trate of silver, chloride of iron, acetate of copper, are precipitated by it.

Mulder subjected this last precipitate to an analysis. 110 parts dried at 248° gave 4 of oxide of copper. 418 parts gave 752 carbonic acid, and 243 water. The azote amounted to 14·87 per cent. Hence the constituents are,

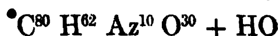
Carbon,	49·06
Hydrogen,	6·46
Azote,	14·87
Oxygen,	25·97
Oxide of copper,	3·64
	100·

He represents the constitution by the formula $C^{80}\ H^{63}\ Az^{10}\ O^{31} + CuO$. He considers it as a compound of 1 atom oxy-protein, and 1 atom oxide of copper, together with a compound of one atom oxy-protein, and 1 atom water.



1 atom oxy-proteate of copper, $C^{40}\ H^{31}\ Az^{5}\ O^{15} + CuO$

1 atom oxy-protein + Aq, $C^{40}\ H^{31}\ Az^{5}\ O^{15} + HO$



$C^{80}\ H^{62}\ Az^{10}\ O^{30} + HO$

Chloroxy-proteates.—Chloro-proteic acid, when dissolved in barytes water, and a current of carbonic acid passed through the solution to throw down the excess of barytes, and finally, when filtered, gives a barytes salt, the constituents of which are constant. Alcohol being added to the aqueous solution, the new salt is precipitated while the chloride of barium remains in solution. The new salt was washed with boiling alcohol and dried at 266°.

When acetate of copper is dropt into the aqueous solution of the barytes salt, as we have it before precipitation by alcohol, bluish flocks precipitate. This precipitate was thoroughly washed and dried at 266°.

With chloride of iron a third salt was obtained. But the analysis of it was found difficult.

The barytes salt being subjected to analysis was found composed of,

Carbon,	44·91
Hydrogen,	5·65
Barytes,	11·88
Chlorine,	1·70
	64·14

What is wanting to make up the hundred consists, doubtless, of azote and oxygen.

The copper salt contained,

Carbon,	48·94
Hydrogen,	6·33
Chlorine,	1·73
Oxide of copper,	3·48
	60·48

The ferruginous salt contained,

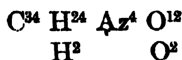
Carbon,	48·07
Hydrogen,	6·21
Chlorine,	1·76
Peroxide of iron,	2·37
	58·41

These analyses would require repetition, and the quantity of azote should be determined.

Xantho-proteic Acid.—This name has been given by Mulder to a yellow coloured acid, obtained first by Fourcroy, by treating fibrin or albumen with nitric acid. During the action azotic gas is evolved, while oxalic acid and ammonia are formed. This acid was analyzed by Mulder, who found it composed of,

Carbon,	51·32	or 34 atoms	= 25·5
Hydrogen,	6·575	or 26 atoms	= 3·25
Azote,	14·	or 4 atoms	= 7·00
Oxygen,	28·105	or 14 atoms	= 14·00
	100·000		49·75

He considers it as a compound of,

1 atom xantho-proteic acid, . .  C^{34} H^{24} Az^{4} O^{12}

2 atoms of water, . . H^{2} O^{2}



C^{34} H^{26} Az^{4} O^{14}

Mulder confirmed these views by analyzing several of the salts of xantho-proteic acid.*

He dissolved pure xantho-proteic acid in ammonia, and the beautiful red liquid formed was evaporated on the water bath till all the uncombined ammonia was driven off. The residue was divided into two portions, the first of which was dried, and the other again dissolved in water, and a current of chlorine gas passed through it. The dried portion when heated to 212° gave out ammonia. It lost its red colour and became orange yellow. It was analyzed after being dried at 284°. 326 parts gave 618 of carbonic acid and 198 of water. The azote per cent. was estimated at 14·37. Hence its constituents are,

Carbon,	51·70	or 34 atoms	= 25·5
Hydrogen,	6·75	or 25 atoms	= 8·125
Azote,	14·37	or 4 atoms	= 7·000
Oxygen,	27·18	or 13 atoms	= 13·000
	100·		53·625

It is obviously composed of one atom xantho-proteic acid, and one atom water. The ammonia had escaped and the hydrated acid remained.

When a current of chlorine was passed through the ammoniacal solution of xantho-proteic acid it lost its red colour and white flocks with a shade of yellow precipitated. When washed and dried at 212°, these flocks became lemon yellow. This substance being analyzed was found to be a compound of two atoms of hydrated xantho-proteic acid, and one atom of chlorous acid. The analysis gave,

Carbon,	49·61	or 68 atoms	= 51·
Hydrogen,	6·22	or 50 atoms	= 6·25
Azote,	12·89	or 8 atoms	= 14·
Oxygen,	23·29	or 26 atoms	= 26·
Chlorous acid,	7·36	or 1 atom	= 7·5
	99·37		104·75

When the lemon yellow powder is dissolved in ammonia, azotic gas is evolved. If we evaporate to dryness and dissolve off the salamoniac by alcohol, we have the xantho-proteic acid in a state of purity.†

* Ann. der Pharm. xxviii 78. † Ibid. xxxvi. 81.

SECTION I.—OF ALBUMEN.

The term *albumen* employed by Pliny to denote the white of an egg,* began, about the end of the last century, to be applied to certain organic substances, which have the property of coagulating, when heated to the temperature of 159.° In their natural state they are soluble in water, but lose this solubility by coagulation. The word *albumen* does not occur in the table of the new chemical nomenclature, published by the French chemists in 1787. But we find it employed by Fourcroy about the year 1789.† He and Vauquelin seem to have been the first chemists that attempted to fix its meaning with something like precision. Albumen may be obtained sufficiently pure from the *white of an egg* and from the *serum* of blood.

When healthy blood is drawn from an animal, and left at rest, it gradually separates into two portions; namely, a gelatinous-looking substance, containing all the red globules, and called the *crassamentum* or *clot*, and a liquid portion of a greenish-yellow colour, which floats over the clot. This liquid is called the *serum* of the blood.

It was first observed by Dr Harvey, that when serum is heated, it coagulates, and becomes as firm as the coagulated white of an egg, though not so white.‡ The coagulating point, as determined by my thermometer, is 159°. It has been long known that the white of an egg coagulates when heated to the same point. Rouelle and Bouquet, about the year 1776, first compared serum of blood and white of egg together, and concluded that both contained a similar substance. To this substance, as has been already stated, the name *albumen* was applied, from a notion (now known to be erroneous), that it existed in the state of greatest purity in the white of an egg.

The *white of egg* was examined with some care by Neumann, who ascertained its property of being coagulated by heat, alcohol, and acids; found that, in a gentle heat, it might be evaporated to dryness, leaving a yellowish translucent substance, resembling amber in appearance, and still capable of dissolving in cold water. When thus dried, he found that 100 parts of albu-

* Plinii Hist. lib. xxviii. c. 6.

† Ann de Chem. iii. 252.

‡ De Generatione Anim. p. 161.

men were reduced in one case to 10·15, and in another to 14·28 parts.*

It has not hitherto been possible to free albumen from all foreign matters; but it is brought to a state approaching purity by the following process:

Mix the white of eggs with a considerable quantity of distilled water; and rub the mixture intimately in a glass or porcelain mortar, to break down all the membranous cells in which the albumen is lodged, and allow it to dissolve in the water. Throw the whole on a filter of very bibulous paper, and raise the temperature of the filtered liquor to 160°. The albumen will coagulate in white flocks. Let it subside to the bottom of a cylindrical glass in which the whole liquid has been put. Draw off the clear liquid, and add a new portion of distilled water. Agitate well, allow the albumen again to subside, and draw off the water a second time. This process may be repeated a third time, after which the albumen is to be dried in a gentle heat. Reduce it to a fine powder, digest it in alcohol till that liquid ceases to dissolve any thing. Finally, dry it over the steam-bath. It is now as pure as it is in our power, with our present knowledge, to make it.†

Albumen purified in this manner, when burnt, leaves about 2 per cent. of a gray-coloured ash; doubtless, the earthy salts (chiefly phosphates) which the white of egg contained. Scheele observed, that when the white of an egg was dissolved by boiling it in very dilute acids, it was again precipitated by adding some concentrated acid. During this precipitation a smell of sulphuretted hydrogen was perceptible, showing clearly that it contains sulphur.‡

Albumen prepared in this way is transparent, and has an amber colour. When put into water it swells up, becomes opaque and white, and assumes the appearance of coagulated white of egg. According to Chevreul, 1000 parts of water dissolve 7 parts of coagulated albumen.

It dissolves in concentrated muriatic acid, and the solution, as

* Neumann's Chemistry, p. 554.

† It will not be freed from soda nor from the earthy phosphates which may have existed in white of egg. To get rid of these it must be treated with an acid.

‡ Scheele's Chemical Essays, p. 268.

was first noticed by Caventou and Bourdois, has a fine blue colour. The addition of water precipitates the albumen white; but the acid still retains its blue colour. Caustic potash or soda dissolves it, and the solution has the property of blackening silver. Coagulated albumen and fibrin possess exactly the same properties.

Uncoagulated albumen seems to possess acid characters, though it does not alter the colour of vegetable blues. In the serum of blood, it is combined with soda. When we add a solution of a metallic salt to the serum of blood, and then drop in as much caustic potash as will decompose the salt, the metallic oxide does not precipitate, but remains in solution united to the albumen.

When to a solution of albumen we add acetic acid, and then drop into it prussiate of potash, a copious white precipitate falls. This is one of the most delicate tests of the presence of albumen in liquid.

Protosulphate of iron and sulphate of copper, according to Schübler, precipitate a very dilute solution of albumen; but if we increase the quantity of the metallic salt, the precipitate again dissolves.

The salts of tin, lead, bismuth, silver, and mercury, precipitate albumen white. The subacetate of lead gives a precipitate with a very minute quantity of albumen. Corrosive sublimate precipitates albumen from a liquid containing only $\frac{1}{2000}$th of its weight of that principle. The precipitate is a compound of corrosive sublimate and albumen. By this combination, the poisonous qualities of corrosive sublimate are destroyed. Hence, the white of egg constitutes the best antidote to this poison. According to Orfila the albuminate of corrosive sublimate (if the term may be permitted) is composed of,

Albumen,	62·22	or 28
Corrosive sublimate,	37·78	or 17
	100·00	

According to Bostock, of

Albumen,	88·89	or 136 = 28 × 5 nearly.
Corrosive sublimate,	11·11	or 17
	100·00	

Albumen was analyzed by Gay-Lussac and Thenard, by Michaelis and by Prout. Gay-Lussac and Thenard merely dried the white of an egg in the temperature of 212°, and analyzed it without any attempt to purify it.* Dr Prout employed albumen from the serum of the blood of a patient labouring under a slight inflammation. Mulder has made a more recent analysis, and took the precaution to purify his albumen by the process described at the beginning of this section. Hence it would be free from a small portion of mucus, which is known to exist in the white of egg. The result of all these analyses will be seen in the following table:

		Michaelis.			Mulder.	
	Gay-Lussac & Thenard.	From arterial blood.	From venous blood.	Prout.	White of egg.	Serum of blood.
Carbon,	52·883	53·009	52·660	49·750	53·960	54·398
Hydrogen,	7·540	6·993	7·350	7·775	7·052	7·024
Azote,	15·705	15·562	15·505	15·550	15·696	15·843
Oxygen,	23·872	24·436	24·484	26·925	23·292	22·744
	100·	100·	100·	100·	100·	100·

But Mulder has more recently subjected albumen to a new analysis, and determined the phosphorus and sulphur which it contains. The following are his results:†

	From Eggs.	From Serum.
Carbon,	54·48	54·84
Hydrogen,	7.01	7·09
Azote,	15·70	15·83
Oxygen,	22·00	21·23
Phosphorus,	0·43	0·33
Sulphur,	0·38	0·68
	100·	100·

He represents its constitution by the formula, 10 (C^{40} H^{31} Az^{5} O^{12}) + Ph + S^2, or ten atoms protein united to one atom phosphorus and two atoms sulphur. If we calculate from this formula we get,

400 atoms carbon,	= 300	or per cent.	54·33
310 atoms hydrogen,	= 38·75	...	7·02
50 atoms azote,	= 87·50	...	15·84
120 atoms oxygen,	= 120·00	...	21·73

* Recherches Physico-Chemiques, ii. 331. † Ann. der Pharm. xxviii. 74.

1 atom phosphorus,	= 2·00	...	0·36
2 atoms sulphur,	= 4·00	...	0·72
	552·25		100·

Still more lately albumen has been subjected to a careful analysis by Dr Scherer in Liebig's laboratory.* He analyzed albumen from blood, from eggs, from the liquor of a hydrocele, and from pus. The result came so near those of Mulder, that it seems unnecessary to state them. It has been already stated, that his formula for protein is $C^{48} H^{36} Az^{6} O^{14}$. It differs from that of Mulder only by an atom of hydrogen. In the present state of our knowledge, it is difficult, if not impossible, to decide which of the two formulas is nearest the truth.

It is evident from the analyses that the chemical constitution of albumen from the egg and from serum is identical. Yet reagents do not in all cases produce the same effect upon each. Chevreul informs us, that ether and oil of turpentine coagulate white of egg, while, according to Tiedemann and Gmelin, they do not produce the same effect on the serum of blood.

SECTION II.—OF ALBUMEN FROM SILK.

This substance was first particularly examined by M. Mulder in 1836. He obtained it by the following process.

Silk was treated with boiling water till every thing soluble in that liquid was taken up. The aqueous solution was evaporated to dryness and the residue digested in alcohol and ether. The matter not acted upon by these liquids was a mixture of coagulated albumen and gelatin. Boiling water dissolved the latter substance and left the albumen in a state of purity.

It is brittle, easily reduced to powder, and heavier than water. When placed on a hot iron it is charred and emits the smell of burning horn. It burns with flame, leaving a large quantity of white ashes. When distilled *per se* it gives out much carbonate of ammonia and empyreumatic oil. A dry portion of it being left for 24 hours in concentrated sulphuric acid remained unaltered. But when heat was applied it was charred with the evolution of sulphurous acid gas. Moist albumen dissolves in sulphuric acid at the common temperature of the atmosphere. In dilute sulphuric acid it is not soluble even when heat is applied

* Ann. de Pharm. xl. 36.

Nor does it dissolve in cold nitric acid; but it is easily soluble in that acid when assisted by heat. Moist albumen dissolves in nitric acid at the common temperature, and oxalic acid is formed. It is not acted on by muriatic acid unless heat be applied when it is dissolved. Moist albumen dissolves in it at the ordinary temperature of the atmosphere. By phosphoric acid and heat it is charred and decomposed.

When dissolved in concentrated acetic acid, the solution has a fatty feel, which Mulder considers as a remarkable distinguishing character. When prussiate of potash is dropt into this solution a beautiful green precipitate falls, which is insoluble in water. By this property a minute quantity of this albumen may be discovered.

It dissolves in potash, soda, and ammonia, and is precipitated again by acids. If we add acetic acid to the potash solution it will not blacken silver. It is insoluble in carbonated potash, soda, or ammonia.*

According to Mulder's analysis it is composed of,

Carbon,	.	54·005
Hydrogen,	.	7·270
Azote,	.	15·456
Oxygen,	.	23·269
		100·000†

These numbers come sufficiently near the various analyses of albumen from blood and eggs to show that all these substances are isomeric.

SECTION III.—OF CASEIN.

Milk is the well known liquid secreted by the females of the whole class of mammalia to nourish their new-born offspring. The milk of the cow has been used as a common article of food from the earliest ages. Hence its appearance, its taste, and its nourishing properties are known to every person.

Milk underwent a chemical examination from Neumann. He ascertained the quantity of water which it contained, and Dr Lewis showed that its boiling point was the same as that of water; that it is coagulated by acids and also by alkalies. The co-

* Poggendorf's Annalen, xxxvii. 608. † Ibid. xl. 270.

agulum by acids falls to the bottom of the serum, but that by alkalies swims on the surface.*

Neumann also made some experiments on *cheese*, a well-known preparation of *curd*. He tried the action of water, nitric acid, sulphuric acid, muriatic acid, and caustic alkalies, both fixed and volatile; and found that they dissolved cheese either partially or completely.

Scheele examined milk and *curds* in 1780, and was the first person who compared curds with coagulated white of egg. He showed that the properties of both were the same. Milk is coagulated by acids, and the coagulum formed is a compound of the acid employed and curd. The mineral acids when used in excess dissolve a portion of the precipitate, but the vegetable acids dissolve little or nothing. Hence the reason why more curd is obtained when milk is coagulated by vegetable than by mineral acids.†

The first attempt to make a regular analysis of milk was by Parmentier and Deyeux, in a memoir which gained the prize offered by the Society of Medicine of Paris, for the year 1790.‡ These chemists examined the *curd* of milk in considerable detail, and determined many of its properties, though they did not obtain it in a state of purity. They distinguished it by the name of *matiere caséeuse.*

Fourcroy in his *Systeme des Connoissances Chimiques*, published about the beginning of the present century, gives a pretty detailed account of the *curdy* part of milk, chiefly taken from the Memoir of Parmentier and Deyeux. He distinguishes it, as these chemists did, by the name of *caseous matter.*§

In 1808, the second volume of the Animal Chemistry of Berzelius was published in Stockholm. It contains an excellent analysis of milk,‖ and a detailed examination of the characters of the curdy portion, which he distinguishes by the name of *ost*, (cheese). He pointed out some difference in the characters of

* Lewis's Neumann's Chemistry, p. 573.

† Scheele's Chemical Essays, p. 265.

‡ See an abstract in Ann de Chim. vi. 183. The memoir itself was published in Paris in 1800.

§ Vol ix. p. 515 of the English translation.

‖ Föreläsningor i Djuskemier, ii. 409.

ost and albumen, which Scheele had from his observations pronounced identical.

I do not know who first applied to the curdy part of milk the name *casein*. But it occurs in the 27th volume of the *Dictionnaire des Sciences Medicales*, published in 1818. The word *caseus*, applied to the same substance, is found in the *Dictionnaire de Chimie* of Klaproth and Wolff, the French translation of which appeared in 1810.

Casein may be obtained from cow's milk by the following process:

Mix skimmed milk with dilute sulphuric acid. The casein and acid unite and precipitate in the state of a white curd. Let the curd be collected on a filter, and well washed with water to remove the whey which it contains. Thus cleaned, it is to be mixed with water and digested over carbonate of barytes. The sulphuric acid unites with the barytes, while the casein set at liberty dissolves in the water. When this liquid is filtered to free it from the sulphate of barytes and the excess of carbonate employed, it has a pale yellow colour, and resembles in consistence a solution of gum. When heated in an open vessel it emits the smell of boiling milk, and a white pellicle forms on the surface, similar to that which is formed on the surface of boiling milk. When the liquid is evaporated to dryness in a gentle heat we obtain the casein in the state of an amber-coloured mass, which is still soluble in water. The aqueous solution is coagulated by all acids, even by the acetic, especially when assisted by heat. This property distinguishes casein from albumen; which last is not precipitated by acetic acid.

Braconnot assures us that casein obtained by the above process is not quite free from impurity. He recommends the following process as better. Take 400 parts of curd formed by rennet, and well washed in boiling water to get red of the whey. Mix them with one part of bicarbonate of potash in crystals, and a sufficient quantity of water. Heat the mixture, an effervescence takes place, and the curd and alkali combine and dissolve in the water. When this solution is cautiously evaporated to dryness it constitutes the *soluble casein* of Braconnot, a substance which he recommends for a variety of useful purposes.

To obtain pure casein, dissolve a quantity of soluble casein in boiling water. Pour the solution into a funnel, having its

beak shut up, and let it remain at rest for 24 hours. A quantity of cream collects on the surface, which is separated by allowing the clear solution to pass through the funnel, retaining the cream. Pour into this clear liquid a little sulphuric acid. A curdy precipitate falls, consisting of casein combined with sulphuric acid. Wash this precipitate, heat it in water mixed with a very small quantity of carbonate of potash, scarcely sufficient to dissolve all the matter. We obtain a mucilaginous liquid, which, while still hot, must be mixed with its own bulk of alcohol. No precipitate should fall till 24 hours after the mixture. The precipitate consists of butter, sulphate of potash, and a portion of casein. Let the liquid be passed through a cloth. We obtain a transparent liquid, which, when evaporated to dryness, leaves pure casein.*

When the aqueous solution of casein is left to itself it gradually alters, gives out the smell of old cheese, and becomes ammoniacal.

When alcohol is poured upon casein, dried in a low heat, it becomes opaque, and assumes the aspect of coagulated albumen. The alcohol abstracts the water with which it was united, and thus occasions the alterations. At the same time the alcohol dissolves a portion of the casein, which remains when the alcoholic liquid is evaporated to dryness. Casein is still more soluble in boiling alcohol. The excess precipitates as the liquid cools. By this solution the characters of the casein are not in the least altered.

Anhydrous casein, or casein digested or dissolved by alcohol, swells in water, and gradually dissolves into a mucilaginous frothy mass, which becomes transparent and liquid when heated, and then assumes the original characters of casein dissolved in water.

Acids act upon casein very nearly as upon albumen. With a little acid it forms a compound soluble in water; but when the quantity of that acid is increased, the compound becomes little soluble. By washing with water we may remove this excess, and thus render it again soluble in water. The precipitate by acetic acid may be again dissolved. But much more acid is necessary for that purpose than is required for albumen or fibrin. Solutions of casein in acids are precipitated by prussiate of po-

* Ann. de Chim. et de Phys. liii. 343.

tash. But phosphoric and arsenious acid, according to Braconnot, do not precipitate casein, though, when we add prussiate of potash to a solution of casein containing phosphoric acid, a copious precipitate falls.* Alcoholic solutions of casein are not precipitated by acids. And alcohol dissolves readily the precipitates thrown down from water by acids.

Casein combines with the alkalies without undergoing any alteration, unless the alkaline solutions be concentrated and heat be applied. In that case the solution becomes brown, ammonia is given out, and an alkaline sulphuret is formed.

Casein combines with the alkaline earths. If the quantity of earth be small, the compound is soluble, and the earth is not precipitated by exposure to the air, or by passing through the liquid a current of carbonic acid gas. Indeed casein, as extracted from milk, appears to contain caseate of lime. When casein is placed in contact with an excess of hydrate of lime, a bulky compound is formed very little soluble in water. When this compound is boiled in water, the casein is gradually decomposed. A kind of extractive, soluble in water, is formed, from which oxalic acid precipitates lime.

If we heat sugar with a concentrated solution of casein, it loses its consistence and becomes very fluid. But if we increase the quantity of sugar considerably, the casein separates in curdy masses or clots. But when washed these clots again dissolve in water. When casein is mixed with gum-arabic, it loses its solubility entirely; owing, in the opinion of Braconnot, to a free acid and earthy salts contained in the gum.

Solution of casein in water is precipitated by all the earthy and metallic salts capable of precipitating uncoagulated albumen. Tannin throws it down both from its aqueous and alcoholic solution.

Like albumen it is capable of existing in two states, uncoagulated and coagulated. The characters of uncoagulated casein have been given. We must now state the properties of coagulated casein.

For coagulation it requires the boiling temperature or *rennet*. When an aqueous solution of casein or skimmed milk is mixed with *rennet* and gently heated, coagulation takes place. Rennet is formed by digesting the innermost membrane of a calf's sto-

* Ann. de Chim. et de Phys. liii 344.

mach in cold water. A small quantity of a peculiar substance is dissolved, to which the name *pepsin* has been given, because it has the extraordinary property of dissolving food and converting it into chyme in the stomach of living animals. A very minute quantity of pepsin is sufficient to coagulate a great quantity of milk. Berzelius evaporated a quantity of rennet to dryness in a gentle heat. He mixed one part of the dry residue with 1800 parts of milk, and heated the whole to 122°. The whole casein was so completely coagulated, that scarcely a trace of it could be detected in the whey. The dry rennet being separated was found to weigh 0·96. So that one part of pepsin coagulated 45000 parts of milk.*

Coagulated casein, when pure and dried, is hard, translucent, and yellowish. Unless it be well freed from all traces of *butter*, it has a resinous lustre. This may be removed by digesting the coagulated casein in ether, which dissolves the butter without altering the casein. When put into water it softens and swells; but does not dissolve. When strongly heated before it has been quite dried, it is rendered soft without melting, and becomes elastic like caoutchouc. If the temperature be increased, it swells, melts and burns with flame. The products obtained when it is distilled are the same as those given by albumen. The compounds of coagulated casein with acids and alkalies are similar to those of uncoagulated albumen with the same bodies. But when the acid is withdrawn by means of carbonate of barytes or carbonate of lime, the casein does not dissolve in water, as happens with uncoagulated casein.

Coagulated casein (or *cheese*, as it is called in common language,) is soluble in concentrated sulphuric acid, from which it is precipitated by water. It dissolves in nitric acid of 1·29, to which it communicates a yellow colour. Muriatic acid dissolves it very slowly, requiring to be continued for several days. The solution, like that of albumen and fibrin, becomes blue, if the temperature has exceeded 60°. By degrees the colour changes to a dirty violet. When the acid is saturated with potash, the colour disappears, and the cheese is precipitated greyish-white. With concentrated acetic acid it forms a jelly, and dissolves when we add water and apply heat. But a great deal of acid is necessary. It is very soluble in the hydrates and in the carbonates of

* Traité de Chimie, vii. 601.

potash and soda, when diluted with water and cold. Caustic ammonia dissolves it very slowly and imperfectly.

When cheese coagulated by rennet is burnt, it leaves 6 per cent. of subsesqui-phosphate of lime, and half a per cent. of caustic lime, which had been in combination with the casein in the milk.

When cheese is long kept, it undergoes peculiar alterations, which have been investigated by Braconnot.* He mixed 270 grammes of skim-milk cheese with a litre of water, and left the mixture a month to putrefy, at a temperature between 68° and 77°. The greatest part of the cheese dissolved, and the solution was separated from the undissolved portion by filtration. It had a putrid smell, without anything sulphureous. Being evaporated to the consistence of honey, it gradually congealed into a granular mass. Alcohol dissolved a portion of this matter, and left a portion untouched.

The undissolved portion was dissolved in water and treated with animal charcoal, which deprived it of its colour. Being now left to spontaneous evaporation, it gave small brilliant crystalline vegetations, and fine needle-form crystals, constituting cauliflower rings round the borders of the liquid. To obtain this substance white, it was necessary to dissolve and crystallize it several times. Braconnot distinguished this substance by the name of *aposepedin.* † Proust had previously called it *caseic oxide.* Its properties have been already detailed in a former part of this volume. The first attempt to analyze casein was made by Thenard and Gay-Lussac. The casein which they employed was obtained by spontaneous coagulation. It was washed thoroughly with water, and then dried and pulverized. It was then burnt with chlorate of potash, and the quantity of carbonic acid, &c. obtained, determined from which the constituents were inferred.‡ Mulder has shown that its base is protein, and that it consists of ten atoms of protein united to one atom of sulphur, or 10 $(C^{40} H^{31} Az^{5} O^{12}) + S$. Dr Scherer also subjected it to analysis.§ Milk was mixed with twice its bulk of alcohol; and the coagulum was boiled repeatedly in alcohol and ether. When all the butter was removed, the coagulum was boiled in water to se-

* Ann. de Chim. et de Phys. xxxvi. 159.

† From ἀπο and σηπεδων, *putrefaction.*

‡ Recherches Physico-Chimiques, ii. 332.

§ Ann. der Pharm. xl. 40.

parate the sugar of milk. It was then dried at 212°. Its constituents were,

Carbon,	.	54·825
Hydrogen,	.	7·153
Azote,	.	15·628
Oxygen, Sulphur, }	.	22·394
		100·000

Several other analyses gave nearly the same result.

SECTION IV.—OF FIBRIN FROM BLOOD.

When the crassamentum of blood is put into a linen cloth, and carefully washed till all the red colouring matter is removed, the substance which remains has a fibrous texture, and is, on that account, distinguished by the name of *fibrin*. This name seems to have been imposed by Fourcroy and Vauquelin; at least I have not observed it in the writings of any earlier chemist.

It was long the opinion of physiologists, that the globules of the blood consisted of a nucleus of fibrin enclosed in a vesicle of colouring matter. Hence it was supposed was the reason why it exists in the crassamentum. But later observations have considerably modified this opinion. Piorry and Scelles de Mondezert have remarked, that, if we cautiously and rapidly remove the serum which floats on the crassamentum, we will frequently find it become opaline and muddy, and finally covered with a skin analogous, if not identical with fibrin.* According to Muller, if we amputate the thigh of a frog, and after mixing the blood that flows out with an equal quantity of water, holding sugar in solution, throw the whole upon a moistened filter, the red globules, which are very large in that animal, are retained upon the filter, while a colourless and clear liquid passes through. In this liquid, a coagulum of fibrin speedily appears.

From these facts, there seems no reason to doubt, that the fibrin exists in the serum of blood as well as the albumen, and that the globules consist of the red-colouring matter, and a white insoluble substance analogous to coagulated albumen or fibrin. Indeed, Lecanu has shown, by numerous experiments, that the

* Lecanu, Etudes Chimiques sur le Sang Humain, p. 43.

globules consist of three distinct substances, namely, hematosin, albumen, and fibrin.*

Fibrin may be procured likewise from the muscles of animals. Mr Hatchett cut a quantity of lean beef into small pieces, and macerated it in water for fifteen days, changing the water every day, and subjecting the beef to pressure at the same time, in order to squeeze out the water. The shreds of muscle, which amounted to about three pounds, were now boiled for five hours every day for three weeks in six quarts of fresh water, which was regularly changed every day. The fibrous part was now subjected to pressure, and then dried on the water-bath. In this state, it possessed the characters of fibrin.†

It is very difficult to free the fibrin of blood completely from hematosin. The easiest way is to stir new-drawn ox-blood rapidly with a stick. The fibrin adheres to the stick. Let it be taken off, and washed in cold water till that liquid ceases to be coloured by it. Then steep it in water for twenty-four hours, washing it frequently and carefully during that time. Finally, let it be digested in alcohol, or still better in ether, to separate a fatty matter which it still contains.

Fibrin, when dried, assumes a dirty-yellow colour, and becomes hard and brittle, but continues opaque. When put into water, it imbibes that liquid, and recovers its original appearance, and nearly its original weight. It has neither taste nor smell. When heated, it does not alter till it reaches the point of decomposition. It then melts, swells greatly, catches fire, and burns with a yellow flame, giving out much smoke. It is insoluble in water, whether cold or hot. When boiled in that liquid, it contracts and becomes at last extremely friable. The water becomes muddy, and if we evaporate it to dryness, we obtain a solid, brittle, yellow substance, having the smell of boiled meat, and soluble in water. This substance does not assume the form of a jelly, and is precipitated by tannin in insulated flocks, which do not unite into an elastic mass like tannate of gelatin.

Fibrin, like albumen and casein, possesses both the characters of an acid and a base. The concentrated acids cause it to swell, and to become gelatinous and transparent. With sulphuric acid, it swells into a yellow jelly, but does not dissolve. Heat is evolv-

* Lecanu, Etudes Chimiques sur le Sang Humain, p. 5.

† Phil. Trans. 1800, p. 327.

ed, and, unless the temperature is kept down, sulphurous acid is disengaged, and the fibrin becomes black. When the acid is dilute, or when water is poured on the jelly, the fibrin suddenly contracts to less than its original bulk. This contracted mass is a compound of sulphuric acid and fibrin. When it is collected on a filter, and washed with water, it becomes transparent and gelatinous, and at last dissolves completely in water. This soluble matter is a neutral compound of sulphuric acid and fibrin. The addition of sulphuric acid renders it insoluble as at first.

Nitric acid gives fibrin a yellow colour. When cold and dilute, it forms two compounds with fibrin, as sulphuric acid does, and having the same characters. But when heat is applied, and the acid is strong, azotic gas is given out, the acid becomes yellow, and the fibrin is converted into a yellow or orange mass, which does not dissolve in water. This substance was first described by Fourcroy under the name of *yellow acid.*

Pyrophosphoric acid produces with fibrin the same phenomena as sulphuric acid. With common phosphoric acid, fibrin does not swell into a jelly, but forms a compound soluble in water, and not precipitated by an excess of acid.

In concentrated acetic acid fibrin becomes immediately soft and transparent, and, with the assistance of heat, is converted into a tremulous jelly. By adding hot water, this jelly is completely dissolved with the evolution of a small quantity of azotic gas. The solution is colourless, and has a mawkish and slightly acid taste. During its evaporation a transparent membrane appears on the surface, and after a certain degree of concentration the gelatinous substance is again reproduced. When completely dried it is a transparent mass which reddens litmus-paper, but is insoluble in water without a fresh addition of acetic acid. When ferrocyanate of potash, an alkali, or sulphuric, nitric, or muriatic acid is dropped into this solution a white precipitate falls. The acid precipitate is a compound of fibrin and the acid. If it be washed, a certain portion of acid holding fibrin in solution is carried off, and the remainder is soluble in water. This solution contains a neutral compound of the acid and fibrin. The addition of a little more of the acid causes it to precipitate again. *

* Berzelius, Annals of Philosophy, ii. 20.

In weak muriatic acid fibrin shrinks and gives out a small quantity of azotic gas; but scarcely any portion is dissolved even by boiling; nor does the acid liquid afford any precipitate with ammonia or ferrocyanate of potash. The fibrin thus treated is hard and shrivelled. When repeatedly washed with water it is at last converted into a gelatinous mass, which is perfectly soluble in warm water. The solution reddens litmus-paper, and yields a precipitate with acids as well as alkalies. Fibrin, therefore, combines with muriatic acid in two proportions. The one gives a neutral compound soluble in water, the other with an excess of acid is insoluble, but becomes soluble by the action of pure water.*

In caustic alkali fibrin increases in bulk, becomes transparent and gelatinous, and at length is completely dissolved. The solution is yellow with a shade of green. Acids occasion in it a precipitate which gradually becomes confluent. Alcohol occasions a precipitate in it. Some alteration is produced upon the fibrin by the alkali, but nothing in the least similar to a soap is formed.†

Ammonia behaves with fibrin as potash does, only the action is slower.

When sulphate of soda or nitrate of potash is put into blood, it is prevented from coagulating, and of course the fibrin does not separate.

Fibrin possesses exactly the characters of coagulated albumen.

Fibrin from blood was analyzed by Gay Lussac and Thenard,‡ by Michaelis,§ and more recently by Mulder‖ and Vogel.¶ The following table exhibits the result of these analyses:

	Gay Lussac and Thenard.	Michaelis. Arterial.	Michaelis. Venous.	Mulder.	Vogel
Carbon,	53·360	51·374	50·440	53·328	51·76
Hydrogen,	7·021	7·254	8·228	6·830	7·09
Azote,	19·934	17·587	17·267	15·465 **	18·05
Oxygen,	19·685	23·785	24·065	24·377	23·10
	100·000	100·000	100·000	100·000	100·00

* Berzelius, Annals of Philosophy, ii. 20. † Ibid.

‡ Recherches Physico-chimiques, ii. 328.

§ *Diss. de partib. constitut. sanguin. arteriosi et venosi.*

‖ Poggendorf's Annalen, xl. 255. ¶ Jour. de Pharmacie, xxv. 587.

** Varrentrapp and Will obtained 16·02 per cent. of azote.—Ann. der Pharm xxxix. 292.

The differences between these results are considerable, probably depending upon the presence of some foreign matter. The mean of the five is as follows:

Carbon,	.	52·05
Hydrogen,	.	7·28
Azote,	.	17·66
Oxygen,	.	23·51
		100·00

Before we can draw any conclusion from these analyses we must know the atomic weight of fibrin. Berzelius made some experiments to show that its atomic weight may be determined, but has stated no numerical results. Mulder made several salts of fibrin and subjected them to analysis. It will be worth while to state the results which he obtained.

1. *Fibrate of copper.*—When sulphate of copper is added to a solution of fibrin in caustic potash, green flocks of fibrate of copper precipitate. This salt being analyzed gave,

Fibrin,	. 798 or 64·35	= 1 atom.
Oxide of copper,	62 or 5·	= 1 atom.

3. *Subsesqui-fibrate of lead.*—It was obtained by mixing subacetate of lead with fibrate of potash. It was composed of,

Fibrin,	. 38331 or 63.896	= 1 atom.
Oxide of lead,	5599 or 21·	= 1½ atom.

3. *Fibrate of silver.*—It was prepared by dissolving fibrin in acetic acid and mixing the solution with nitrate of silver. It was composed of,

Fibrin,	. 6984 or 62·52	= 1 atom.
Oxide of silver,	403 or 3·625	= ½ atom.

The mean atomic weight of fibrin deduced from these three analyses is 63·588.

4. Mulder passed a current of dry muriatic acid over dry fibrin, till no more absorption took place, and then passed through the apparatus a current of dry air till muriatic acid fumes no longer made their appearance. 1112 of fibrin by this treatment increased in weight 80. Hence the muriate of fibrin was composed of,

Muriatic acid,	80 or 4·625	= 1 atom.
Fibrin,	. 1112 or 64·287	= 1 atom.

The mean of all these analyses gives us 63.76 for the atomic

weight of fibrin, or rather protein. Now the numbers which agree best with the mean of the analyses, and with the atomic weight deduced from the experiments of Mulder, are the following:

45 atoms carbon,	= 33·75	or per cent.	52·03
38 atoms hydrogen,	= 4·75	...	7·32
6½ atoms azote,	= 11·375	...	17·53
15 atoms oxygen,	= 15·00	...	23·12
	64·875		100·00

More lately Mulder has endeavoured to determine the quantity of sulphur and phosphorus which occurs in fibrin. These two substances he considers as combined and forming a sulphuret of phosphorus. By an ultimate analysis of fibrin he got,

Carbon,	54·56
Hydrogen,	6·90
Azote,	17·72
Oxygen,	22·13
Phosphorus,	0·33
Sulphur,	0·36
	102·00*

He represents the constitution by 10 (C^{40} H^{31} Az^{5} O^{12}) PhS. Calculating from this, we get,

400 carbon,	= 300·	or per cent.	54·52
310 hydrogen,	= 38·75	...	7·04
50 azote,	= 87·5	...	16·90
120 oxygen,	= 120·0	...	21·35
1 phosphorus,	= 2·	...	0·36
1 sulphur,	= 2·	...	0·36
	550·25		

Fibrin from venous human blood was purified by Dr Scherer,† and subjected to various ultimate analyses; being burnt sometimes with oxide of copper, but in four out of six analyses by chromate of lead. The following is the mean result of these six analyses;

* Ann. der Pharm. xxviii. 74. † Ibid. xl. 33.

Carbon,	54·393
Hydrogen,	6·963
Azote,	15·783
Oxygen, Sulphur, Phosphorus,	22·861
	100·

Numbers which agree exceedingly well with the result of Mulder's analyses. We may therefore conclude that fibrin is a compound of ten atoms protein, with one atom sulphur, and one atom phosphorus, or 10 (C^{40} H^{31} Az^{5} O^{12}) + S + Ph.

SECTION V.—OF FIBRIN FROM SILK.

This species of fibrin has been examined with much ingenuity and skill by M. Mulder.* Raw silk was boiled successively in water, alcohol, ether, and acetic acid, till every thing soluble in these liquids was removed; what remained was considered as *fibrin*. In yellow raw silk it amounted to 53·37, and in white raw silk to 54·04 per cent.

Its colour is white, but it is much softer and more brittle than natural raw silk, and has much less coherence. So that a tuft of it breaks with the greatest facility into an infinite number of very minute threads, spreading out in every direction. Hence neither so beautiful nor so strong a fabric could be woven of it, as of raw silk in its natural state.

It is heavier than water. When burnt it emits the smell of horn. When distilled it gives much carbonate of ammonia, empyreumatic oil, and water, and leaves a bulky charcoal. When thrown upon a red hot plate of iron it melts, or at least becomes soft, swells out, and burns with a light blue flame, and leaves a bulky charcoal.

It is insoluble in water, alcohol, ether, and acetic acid. It is equally insoluble in fat and volatile oils. It dissolves immediately in concentrated sulphuric acid at the common temperature of the atmosphere, forming a light brown thick solution. When heated it becomes first of a beautiful red, then of a brown, and finally of a black colour, while sulphurous acid is given off. From this solution it is not thrown down by water. But when

* Poggendorf's Annalen, xxxvii. 603, and xl. 266.

infusion of nutgalls is added an abundant white precipitate separates. When the solution is diluted with water this matter falls like a jelly to the bottom, but is again dissolved by agitation. When potash is added white flocks fall down, but they are again dissolved, when a great excess of potash is added.

Fibrin of silk is soluble in muriatic acid at the common temperature. When heat is applied the colour becomes brown. It is soluble in nitric acid at the common temperature of the atmosphere, with the exception of a few flocks, which remain undissolved. When heat is applied to the solution oxalic acid is formed. In phosphoric and pyrophosphoric acids it is insoluble at the common temperature of the atmosphere, but dissolves readily when the action of the acid is assisted by heat.

In weak potash ley it remains unaltered, but when the ley is strong the fibrin dissolves in it by the assistance of heat. On adding water to the solution the fibrin separates in flocks. Sulphuric acid also throws it down in minute threads. It is very remarkable that when this fibrin is precipitated from its solutions it always assumes the form of minute threads. When mixed with dry caustic potash and heated while the mixture is kneaded together (*unter kneten*), it is converted into oxalic acid, as Gay Lussac had already observed to have been the case with silk.

It is insoluble in carbonate of potash and in liquid ammonia.

When fibrin of silk is burnt in a platinum crucible a considerable quantity of salt remains behind, which cannot be separated from the fibrin till its texture is destroyed. This ash is partly soluble in water, and the solution reacts weakly as an alkali. When muriatic acid was poured upon it, an effervescence took place, and the whole was dissolved except a little silica. The solution contained lime, iron, magnesia and soda; manganese, common salt, phosphoric acid, and sulphuric acid.

Mulder subjected this fibrin to analysis, and obtained,*

Carbon, .	47·99
Hydrogen, .	6·57
Azote, .	17·35
Oxygen, .	28·09
	100.

* Poggendorf's Annalen, xl. 266.

Mulder found that muriatic acid, combined with the fibrin of silk, so as to form a compound of,

Muriatic acid, .	6·962 or	4·625
Fibrin, . .	93·038 or	61·671

If the two are combined atom to atom, the atomic weight will be 61·671, and the fibrin will consist of,

38 atoms carbon, .	= 28·5	or per cent.	47·60
31 atoms hydrogen,	= 3.875	...	6·47
6 atoms azote, .	= 10·500	...	17·54
17 atoms oxygen, .	= 17·000	...	28·39
	59·875		100

Supposing fibrin of silk to be pure, and Mulder's analysis accurate, it obviously differs in its composition from the fibrin of blood. But the subject is too obscure to warrant any inferences.

SECTION VI.—OF RICOTTIN.

This is a name given (*ricotta*) by the Italians to a substance which exists in milk, but is not separated from the whey by rennet. In Switzerland it goes by the name of *zieger*, and in the Vosges by that of *bracotte*. It has been examined by Schubler, and is considered by him as intermediate between casein and albumen. *

It may be obtained in the following manner :—Coagulate milk by rennet and separate the whey. Raise the temperature of this whey (after it has been filtered) to 167°, and mix it with acetic acid. A new coagulation takes place, and the ricottin is precipitated. In Switzerland it is manufactured into a poor cheese, which is said to be used in that country as food for cattle.

The characters of this substance, as given by Schubler, resemble so closely those of casein, that we can scarcely hesitate i adopting the opinion of L. Gmelin, that ricottin is nothing else than uncoagulated casein united to acetic acid.

Ricottin, in its fresh state, contains 84·4 per cent. of water. It is a white, slimy, mucilaginous substance, very similar to albumen, not thready, and it has a specific gravity of 1·055. Its taste is that of albumen mixed with tallow. When dried it becomes

* Schubler, as quoted by L. Gmelin, Handbuch der Theoretischen Chemie, ii. 1078.

4

greyish-white, opaque, without lustre, hard, friable, and has a specific gravity of 1·355. And when again moistened with water, acquires the taste and smell of soap. The action of reagents on it is the same as on casein.

CHAPTER II.

OF GELATIN.

The term *gelatin* was introduced into chemistry to denote *glue*, when deprived by a chemical process of all its impurities. The name was contrived to point out the characteristic property of pure *glue*. When put into water it swells up into a bulky gelatinous substance, but does not dissolve. When this jelly is heated up to 93° it dissolves in the water; but the whole solution assumes the form of a jelly when it is allowed to cool. It has been shown by M. J. Müller that there are two species of gelatin,—one which is not precipitated from its aqueous solution by the addition of *acetic acid*, while acetic acid precipitates the whole of the second species. As it is necessary to distinguish these two species from each other, the first, which is obtained by boiling skins and bones in water, is called *common gelatin*, or we may give it the shorter appellation of *collin.** The second species, which is obtained by boiling the permanent cartilages, has been called *chondrin* by Müller. We shall describe these two species in succession.

SECTION I.—COMMON GELATIN OR COLLIN.

Glue was well known to the ancients, and is said by Pliny to have been first made by Dædalus, who lived in the time of Solomon, or about 1000 years before the commencement of the Christian era. It was applied by the ancients to the same purposes for which it is used by the moderns. In this country it is made from the clippings or parings of the skins of oxen, or other large and full-grown animals. They are boiled in fresh water till they are dissolved, and the liquid begins to get thick. It is

* From κολλα, glue.

then strained through baskets to separate the undissolved portions, suffered to settle, and then farther evaporated till, on being poured into flat moulds, it concretes on cooling into solid gelatinous cakes, which are cut in pieces, and dried on a kind of mat. In France and Germany glue is made by boiling bones. Some years ago Mr Yardley of Camberwell took out a patent for extracting glue from triturated bones, and contrived an ingenious apparatus for the purpose. It is commonly believed that glue, from ox hides, is stronger than that from bones. I have never had an opportunity of comparing them together, so as to enable me to judge of the validity of this opinion.

Glue consists chiefly of *gelatin;* mixed, however, with various impurities, which may be removed in the following manner:—Put the glue into cold water. It gradually absorbs moisture, and swells into a tremulous jelly, but does not dissolve. Pour off this cold water once in twenty-four hours, and substitute a new portion in its place till the liquid ceases to dissolve any thing from the glue. Let it be now broken in pieces, and suspended in a cloth in a great quantity of water of the temperature of about 60°. Any thing still soluble will be taken up by the water, and the glue left nearly pure. If we now take this jelly and heat it to 122°, it will become liquid, and may be passed through a cloth or a filter, leaving behind it any coagulated albumen and mucus which it may have contained. On cooling it again assumes the form of a jelly, which may be dried in a low heat. It is now pure *gelatin* or *collin.*

Collin thus obtained is colourless, transparent, hard, and exceedingly cohesive. It is insipid, and has no smell. When thrown into water it swells very much, and is converted into a tremulous jelly; but none of it dissolves. This tremulous jelly becomes liquid when heated up to 93°, and again assumes the gelatinous form on cooling.

From the experiments of Dr Bostock, we learn, that when one part of isinglass (which is nearly pure gelatin) is dissolved in 100 parts of hot water, the solution on cooling is wholly converted into a jelly. But one part of isinglass, in 150 parts of water, does not become concrete; though the solution is to a certain degree gelatinous.*

* Nicholson's Jour. xi. 250.

Dry gelatin undergoes no change when kept; but in the gelatinous state, or when dissolved in water, it very soon putrefies; an acid makes its appearance in the first place (probably the acetic,) a fetid odour is exhaled, and afterwards ammonia is formed.

When dry gelatin is exposed to heat, it whitens, curls up like horn, then blackens, and gradually consumes to a coal; but tremulous gelatin first melts, assuming a black colour. When distilled, it yields, like most animal substances, a watery liquid impregnated with ammonia, and a fetid empyreumatic oil; leaving a bulky charcoal of difficult incineration. It is by no means a very combustible substance.

Collin is not sensibly soluble in alcohol,* and when alcohol is poured into a warm concentrated solution, the whole gelatin coagulates into a white, coherent, elastic, and fibrous mass, which adheres strongly to glass, and gelatinizes in cold water, without dissolving. Collin is likewise insoluble in ether and in oils both fixed and volatile.

When a current of chlorine gas is passed through a solution of gelatin in water, a white solid matter collects on the surface, and whitish filaments swim through the liquid. This solid matter, when separated by the filter and purified, possesses the following properties; its colour is white; it is specifically lighter than water; it has little or no taste; when dried in the open air it falls to powder; it is not soluble in boiling water; it dissolves in hot nitric and acetic acids, but precipitates again as the solution cools; when triturated with potash it emits the smell of ammonia; it does not affect vegetable blues.† Bouillon La Grange, to whom we are indebted for these facts, has given the gelatin thus altered the name of *oxygenized gelatin.* It has been recently examined by M. Mulder.‡

When a current of chlorine gas is passed through a solution of isinglass in lukewarm water, no change is apparent at first. But in two or three minutes each bubble becomes surrounded with a white substance, which adheres gradually to the sides of the vessel as a white, elastic, and very cohesive substance. This

* Isinglass dissolves very well in rectified spirits. This property, together with want of colour, distinguishes it from common collin.

† Bouillon La Grange, Nicholson's Jour. xiii. 209.

‡ Ann. der Pharm. xxxi. 332.

frothy-like substance increases more and more. The solution becomes muddy from a small quantity of white flocks interposed through it, while a gelatinous translucent substance collects on the bottom of the vessel. The frothy substance, according to Mulder, is a compound of four atoms of collin, and one atom of chlorous acid, or 4 (C^{13} H^{10} Az^2 O^5) + Cr O^3. The white flocks are composed of C^{13} H^{10} Az^2 O^5 + Cr O^3. The gelatinous substance at the bottom is $1\frac{1}{2}$ (C^{12} H^{10} Az^2 O^5) + Cr O^3.

This chloride of collin is insoluble in water and alcohol. It reacts as an acid, and this property cannot be destroyed by washing it in warm water. It has also the smell of chlorine or rather of chlorous acid. If we dissolve this chloride of collin by means of ammonia, and put the solution into a glass tube standing over mercury, azotic gas is slowly disengaged from it, and the whole becomes a frothy mucus. If we evaporate the ammoniacal solution to dryness over the water bath, and mix the dry residue with alcohol to extract a little sal-ammoniac which it contains, and then dry the precipitate, we get a transparent matter of a pale-yellow colour, which softens in water, melts when gently heated, and gelatinizes imperfectly on cooling. It dissolves in a great deal of water, and in its properties rather resembles gum than gelatin, but reactives exhibit the same phenomena as with unaltered collin.

Chloride of collin becomes gelatinous in acetic acid, and dissolves in it. Water renders the solution muddy, but prussiate of potash causes no precipitate, showing that no albumen has been formed.

If we saturate the solution of chloride of collin with carbonate of potash, and evaporate, we get a mixture of chloride of potassium, and a small quantity of yellow matter.*

So far as is known, neither bromine nor iodine have the property of combining with collin.

When collin is digested with concentrated sulphuric acid, Braconnot has shown that it is converted into leucin, sugar of collin, and a substance containing less azote than collin does. Nitric acid, when digested with collin, causes the disengagement of a little azotic acid gas, the collin is dissolved except an oily matter, which swims on the surface, and converted partly into

* Berzelius, Traité de Chimie, vii. 706.

oxalic and malic acids.* A quantity of artificial tannin is also formed, and when the solution is evaporated to dryness it detonates.

Muriatic acid dissolves glue with great ease. The solution is of a brown colour, and still continues strongly acid. It gradually lets fall a white powder. This solution precipitates tannin in great abundance from water; and may be employed with advantage to detect tannin when an alkali conceals it.

Concentrated acetic acid softens and gradually dissolves collin. The solution does not gelatinize, but the residue when dried still retains the properties of collin. Dilute acids do not prevent collin from gelatinizing on cooling, acetic acid does not precipitate collin from its solutions.

The fixed alkalies dissolve collin with facility, especially when assisted by heat. Dilute alkaline solutions added to liquid collin do not prevent it from gelatinizing. The earths, barytes, strontian, lime, and magnesia have no sensible action on collin, at least they occasion no precipitate.

Collin combines with many salts. It dissolves a considerable quantity of newly precipitated phosphate of lime. Alum does not occasion a precipitate in solution of collin; but if we add an alkaline ley to the mixture, a copious precipitate falls, consisting of collin combined with disulphate of alumina. The precipitate resembles pure alumina: but if we heat it, we easily recognize the presence of animal matter. Persulphate of iron does not precipitate collin. But if we add to the persulphate enough of ammonia to give it a deep red colour, and then mix it with solution of collin, we obtain an abundant precipitate under the form of a thick viscid, light-red clot.

Neither acetate nor diacetate of lead nor sulphate of alumina occasion any precipitate in solution of collin.

If we mix by degrees solution of collin with that of corrosive sublimate, a muddiness is produced which soon disappears. This continues till we have added a certain quantity of the corrosive sublimate. If we now add an additional quantity of this reactive, the collin is thrown down under the form of a white clot, which is coherent and very elastic. Similar precipitations are obtained with nitrate of mercury and protochloride of tin. Solutions of silver and gold do not precipitate collin; but when

* Scheele; Crell's Annals, ii. 17. *English Trans.*

the mixtures are exposed to the solar rays, a certain portion of the metals is reduced. Sulphate of platinum precipitates collin in brown viscid flocks, which become black in drying, and may then be easily reduced to powder. Mr Edmond Davy, to whom we owe the knowledge of this precipitate, informs us that it is composed of

Peroxide of platinum,	56·11 or 14	= 1 atom.
Sulphuric acid, .	20·02 or 5	= 1 atom.
Collin and water, .	23·87	
	100·00	

When the solution of tannin is dropped into collin, a copious white precipitate appears, which soon forms an elastic adhesive mass, not unlike vegetable gluten. This precipitate is composed of gelatin and tannin; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrefaction. It resembles exactly overtanned leather. The precipitate is soluble in the solution of gelatin, as Davy first observed. Neither is the whole tan thrown down, unless the solutions both of tannin and gelatin be somewhat concentrated. Tremulous gelatin, as was first observed by the same chemist, does not precipitate tannin; but if we employ a solution of gelatin so strong that it gelatinizes when cold, and heat it till it becomes quite liquid, it answers best of all for throwing down tannin. It is by this property of forming a white precipitate with tannin that gelatin is usually detected in animal fluids. It is not, however, a perfectly decisive test, as *albumen* is also thrown down by tannin. But collin is precipitated by tannin when in a much more dilute state than albumen. A solution of one part of collin in 5000 parts of water is sensibly precipitated by tannin. When we mix a hot concentrated liquid solution of collin with infusion of nutgalls, a white, curdy precipitate falls, which, if there be an excess of tannin, forms a coherent elastic mass, which constitutes a horizontal layer on the bottom of the vessel. It is insoluble in water and alcohol; though both of these liquids deprive it of a little tannin. When dry, it is black, hard, brilliant, and breaks with a vitreous or rather resinous fracture. In water, it softens and assumes its original appearance. According to Davy, it is composed of

Tannin,	.	46 or 26·5
Collin,	.	54 or 31·1
		100·

According to Schiebel, 26·8 of tannin combine with 22·36 of collin, when 100 parts of collin are precipitated by a great excess of infusion of 1 part of oak-bark in 9 parts of water. When, on the contrary, we mix a very dilute solution of oak-bark with a solution of collin, taking care not to throw down the whole of the collin, we obtain a precipitate, which is deposited slowly, and can scarcely be separated by the filter. This precipitate is composed of,

Tannin,	.	59·25 or 26·5
Collin,	.	100· or 44·72

It would seem from this that the first compound consists of an atom of collin united to an atom of tannin, and the second of two atoms of collin united to one atom of tannin. This would make the atomic weight of collin, 22·36.

According to Mulder, neutral tannate of collin is composed of,

Tannin,	.	10
Collin,	.	13
		23*

The first attempt to analyze collin was made by Gay-Lussac and Thenard. They mixed it with chlorate of potash, and burnt the mixture, and determined the products.† The result was as follows:

Carbon,	.	47·881
Hydrogen,	.	7·914
Azote,	.	16·998
Oxygen,	.	27·207
		100·000

What prevents us from drawing a satisfactory conclusion from this analysis is our uncertainty about the purity of the collin, examined. M. Mulder‡ has analyzed two specimens of collin, which he purified in the following manner: The first specimen

* Ann. der Pharm. xxxi. 124. † Recherches Physico-Chemiques, ii. 336.
‡ Poggendorf's Annalen, xl 279.

was obtained by boiling pure hartshorn in water for two hours, washing the jelly with alcohol, and then with water. In this state, it left 5·406 per cent. of ashes; doubtless consisting of phosphate of lime, which it is well known collin has the property of dissolving. This specimen being subjected to analysis, was found (abstracting the ashes) to be composed of,

Carbon, .	50·048
Hydrogen,	6·560
Azote, .	18·369
Oxygen, .	25·023
	100·000

The second specimen of collin analyzed by Mulder was obtained by boiling very pure isinglass for half an hour in water, evaporating the solution by the water-bath, washing it with alcohol, and then drying it by a steam-heat. It contained 0·64 per cent. of ashes; doubtless phosphate of lime. Its constituents were,

Carbon, .	50·757
Hydrogen, .	6·644
Azote, .	18·313
Oxygen, .	24·286
	100·000

A specimen carefully prepared from isinglass was analyzed in Liebig's laboratory by Dr Scherer.* He obtained,

Carbon, .	50·557
Hydrogen, .	6·903
Azote, .	18·790
Oxygen, .	23·750
	100·000

Four other analyses gave as a mean,

Carbon, .	50·573
Hydrogen, .	7·141
Azote, .	18·458
Oxygen, .	23·528
	100·

* Ann. der Pharm. xl. 46.

He gives as the formula for its constitution, $C^{48}\ H^{41}\ Az^{7\frac{1}{2}}\ O^{18}$. If we calculate from this formula, we get,

48 carbon,	= 36·	or per cent.	49·83
41 hydrogen,	= 5·125	...	7·12
7½ azote,	= 13·125	...	18·14
18 oxygen,	= 18·000	...	24·91
	72·25		100·00

These numbers agree tolerably well with the analyses; but they do not quite agree with the formula of Mulder, which will be given immediately. Scherer's formula, reduced to Mulder's numbers, would be, $C^{13}\ H^{11}\ Az^{2}\ O^{5}$; while Mulder's is, $C^{13}\ H^{10}\ Az^{2}\ O^{5}$; thus differing from Scherer's by an atom of hydrogen.

If we double the formula for collin we get, $C^{96}\ H^{82}\ Az^{15}\ O^{36}$.
If from these we subtract 2 protein, . $C^{96}\ H^{72}\ Az^{12}\ O^{28}$

There remains . . $H^{10}\ Az^{3}\ O^{8}$

This is equal to 3 ($Az\ H^{3}$) + HO + O^{7} or three atoms of ammonia, one atom of water, and eight of oxygen.

Collin when dissolved in water and exposed to heat gradually alters in its properties. Berzelius put a quantity of glue in a gelatinous state into a bottle, which was hermetically sealed. For six successive days it was kept ten hours at the temperature of 176°. During the remaining fourteen hours it was left to cool. It assumed the form of a jelly less and less firm every day. After the sixth day, it did not gelatinize at all. It was limpid and slightly brownish. On opening the bottle, a little air entered. When the liquid was evaporated, it left a transparent brownish mass soluble in cold water.* A similar set of experiments made by M. L. Gmelin had the same result.

Gelatin, like all other constituents of animal bodies, is susceptible of numerous shades of variations in its properties, and of course is divisible into an indefinite number of species. Several of these have been long known and manufactured for different purposes: and many curious varieties have been pointed out by Hatchett in his admirable Dissertations on Shell, Bone, and Zoophytes, published in the Philosophical Transactions for 1797 and 1800. The most important species are the following:

* Traité de Chimie.

Glue.—This well known substance has been long manufactured in most countries, and employed to cement pieces of wood together. It is extracted by water from animal substances, and differs in its qualities according to the substances employed. Bones, muscles, tendons, ligaments, membranes, and skins, all yield it; but the quality is best when skins are employed; and those of old animals yield a much stronger glue than those of young animals. English glue is considered as the best, owing to the care with which it is made. The parings of hides, pelts from furriers, the hoofs and ears of horses, oxen, calves, sheep, &c. are the substances from which it is extracted in Britain, and quantities of these substances are imported for the purpose. They are first digested in lime-water to clean them, then steeped in clean water, laid in a heap till the water runs off, and then boiled in brass caldrons with pure water. The impurities are skimmed off as they rise; and when the whole is dissolved, a little alum or finely powdered lime is thrown in. The skimming having been continued for some time, the whole is strained through baskets, and allowed to settle. The clear liquid is gently poured back into the kettle, boiled a second time, and skimmed till it is reduced to the proper consistency. It is then poured into large frames, where it concretes on cooling into a jelly. It is cut by a spade into square cakes, which are again cut by means of a wire into thin slices; these slices are put into a kind of coarse net-work, and dried in the open air.* The best glue is extremely hard and brittle; it has a dark brown colour, and an equal degree of transparency without black spots. When put into cold water, it swells very much, and becomes gelatinous, but does not dissolve. When glue is soluble in cold water, it is a proof that it wants strength. Dry glue, according to Dr Bostock, contains 10½ *per cent.* of water.†

Size.—This substance differs from glue in being colourless and more transparent. It is manufactured in the same way, but with more care; eel skins, vellum, parchment, some kinds of white leather, and the skins of horses, cats, rabbits, are the substances from which it is procured. It is commonly inferior to glue in strength. It is employed by paper-makers to give

* Clennell. See Johnson's History of Animal Chemistry, i. 315.

† Nicholson's Jour. xxiv. 7.

strength to that article, and likewise by linen-manufacturers, gilders, polishers, painters, &c.*

Isinglass.—This substance agrees with size in being transparent, but it is much finer, and is therefore sometimes employed as an article of food. It is prepared in Russia from the air-bladders and sounds of different kinds of fish which occur in the mouths of large rivers; chiefly different species of *Accipenser*, as the *Sturio stellatus*, *Huso ruthenus*, and likewise the *Siluris glanis*. The bladder is taken from the fish, clean washed, the exterior membrane separated, cut lengthwise and formed into rolls, and then dried in the open air. When good, isinglass is of a white colour, semitransparent, and dry. It dissolves in water with more difficulty than glue, probably because it is not formed originally by solution. From the analysis of isinglass by Hatchett, we learn that it is almost completely convertible into gelatin by solution and boiling. Five hundred grains of it left by incineration 1·5 grain of phosphate of soda, mixed with a little phosphate of lime.

A coarse kind of isinglass is prepared from sea-wolves, porpoises, sharks, cuttle-fish, whales, and all fish without scales. The head, tail, fins, &c. of these are boiled in water, the liquid skimmed and filtered, and then concentrated by evaporation till it gelatinizes on cooling. At that degree of concentration, it is cast on flat slabs and cut into tablets. This species is used for clarifying, stiffening silk, making sticking-plaster, and other purposes.†

SECTION II.—OF CHONDRIN.

When any of the permanent cartilages of the body,‡ as those of the larynx, ribs, or joints, are boiled from twelve to eighteen hours in water, they dissolve more or less completely, and when the solution is sufficiently concentrated, it gelatinizes precisely like *collin*, and when dried constitutes a glue, which may be used for all the purposes to which common glue is applied. It is, therefore, a gelatin; but it differs from collin by several properties first determined by M. J. Müller, who gave it the name of

* Clennell. See Johnson's History of Animal Chemistry, i. 315.

† Fabricius de Ichthyocolla, Jackson on British Isinglass, Phil. Trans. lxiii. and Johnson's Animal Chemistry, i. 231.

‡ The cartilages of the ear and the eyelids excepted, which yield no glue in forty-eight hours boiling.

chondrin;* and in 1841 a set of experiments, serving still farther to characterize it, was published by M. Vogel, Jun.† It may be distinguished by the following properties.

1. It is less brown than collin.

2. It is precipitated completely from its aqueous solution by acetic acid. The precipitate is in very fine flocks, and gives the liquid a white colour. It is not redissolved by an excess of acid; but if we neutralize the acid with carbonate of potash, the precipitate is again dissolved. Acetic acid is incapable of throwing down collin from its aqueous solution, or of rendering that solution muddy.

Vogel found that a similar precipitate was occasioned by most of the mineral acids and organic acids tried. To precipitate by sulphuric acid, we must employ a very small quantity of the acid. If into half-an-ounce of the solution of chondrin we dip a rod moistened with sulphuric acid diluted with six times its weight of water, a precipitate falls. But the addition of a drop of the acid redissolves the precipitate. Sulphurous acid precipitates chondrin, and the precipitate is not redissolved by adding an excess of the acid. Nitric acid precipitates and readily dissolves chondrin. This is the case also with phosphoric acid, but pyrophosphoric acid throws it down and an excess of the acid does not redissolve the precipitate.

Phosphorous acid and fluoric acid precipitate chondrin, and the precipitate is redissolved by an excess of the acids. A current of carbonic acid long enough continued throws down the whole of the chondrin, and does not again redissolve it. The precipitate is a carbonate of chondrin.

The precipitates by arsenic, tartaric, oxalic, and citric acids are not redissolved by an excess of these acids.

3. The aqueous solution of chondrin is precipitated by alum, sulphate of alumina, acetate of lead, and persulphate of iron. These reagents have no action on the aqueous solution of collin. Alum or sulphate of alumina occasions the greatest precipitate. It consists of white compact flocks, which speedily coalesce into balls. The precipitate by acetate of lead or persulphate of iron is in larger or smaller flocks, according as the liquid is more or less concentrated. The addition of a small quantity of alum or sulphate of alumina is sufficient to precipitate the whole chondrin

* Poggendorf's Annalen, xxxviii. 304. † Jour. de Pharm. xxxvii. 494.

from its solution. The precipitate is insoluble in water, whether cold or hot; but an excess of alum or sulphate of alumina immediately dissolves it. Hence, to precipitate chondrin completely by these reagents, we must add them cautiously, and drop by drop, to avoid any excess. The filtered liquor will not gelatinize, and contains very little animal matter.

The precipitate by alum or sulphate of alumina is not redissolved by the addition of a little acetate of potash or of soda, or of common salt; but if a great quantity of these salts be added, the precipitate is redissolved.

The precipitate by acetate of lead is not redissolved by an excess of the reagent. The precipitate by persulphate of iron is abundant and bulky. It is not redissolved by an excess of the reagent unless we apply heat, in which case solution takes place.

4. If to a solution of chondrin we add muriatic acid in very minute quantity, not more than a fraction of a drop, the chondrin is precipitated. A greater quantity of the acid not only does not precipitate but redissolves what may have at first fallen. Muriate of chondrin, (if we can give that name to a mixture of solution of chondrin and muriatic acid,) is not precipitated by prussiate of potash.

5. A very concentrated solution of chondrin is not precipitated by caustic alkaline ley. But this ley precipitates collin; and the precipitate contains a great deal of phosphate of lime.

6. Chondrin is precipitated by chloride of platinum, but not by nitrate of silver.

7. Alcohol throws down chondrin from a concentrated solution in white, consistent, thready flocks. If we filter off the alcohol the chondrin remains translucent and does not seem altered in its properties. For it dissolves in hot water and gelatinizes as before. In this respect chondrin agrees with collin.

The alcohol will be found to have dissolved a small quantity of a substance which is not chondrin. For it dissolves in cold water, does not gelatinize, and is precipitated by tannin. These are the characters assigned to the principle distinguished by Thenard by the name of *osmazome*, about which we at present know very little.

8. The only known animal substance precipitated by acetic acid besides chondrin is *casein*. But the two cannot easily be confounded together. Casein does not gelatinize. Its acid so-

lution is precipitated by prussiate of potash, but the muriate of chondrin is not. Muriatic acid precipitates casein, but dissolves chondrin, and only occasions a precipitate when added in very minute quantity.

9. *Chondrin like collin is precipitated by tannin, chlorine, alcohol and corrosive sublimate.*

Chondrin was subjected to an ultimate analysis by Vogel. He states the constituents to be,

Carbon, .	48·97
Hydrogen, .	6·53
Azote, .	14·55
Sulphur, .	0·32
Oxygen, .	29·63
	100·00

As we have no data to determine the atomic weight of chondrin, we cannot state from this analysis the number of atoms which it contains. Supposing the sulphur accidental, and the azote to be three atoms, the composition would be C^{24} H^{19} Az^{3} O^{11}. Hence we see how much less azote it contains than collin.

The analysis of Mulder approaches pretty near to that of Vogel.* He obtained,

Carbon, .	49·96
Hydrogen, .	6·63
Azote, .	14·44
Sulphur, .	0·38
Oxygen, .	28·59
	100·00

He represents the constitution by the formula, C^{320} H^{260} Az^{40} S O^{140} or 10 (C^{32} H^{26} Az^{4} O^{14}) + S.

Dr Scherer† analyzed chondrin from the cartilages of the ribs. He obtained,

Carbon, .	50·195
Hydrogen, .	7·047
Azote, .	14.908
Oxygen, .	27·850
	100·000

* Ann. der Pharm. xxviii. 328. † Ann. der Pharm. xl. 49.

Chondrin from the cornea of the eye was found composed of,

Carbon,	. .	49·522
Hydrogen,	.	7·097
Azote,	.	14·399
Oxygen,	.	28·982
		100·000

He represents it by the formula $C^{48}\ H^{40}\ Az^{6}\ O^{20}$. Calculating from this we get,

48 carbon,	= 36	or per cent.	50·35
40 hydrogen,	= 5	...	7·00
6 azote,	= 10·5	...	24·68
20 oxygen,	= 20	...	27·97
	71·5		100·

These numbers agree pretty well with the analyses. In comparing the formula of Scherer with that of Mulder we must leave out the sulphur which Scherer did not attempt to estimate. If we reduce Scherer's formula to that of Mulder it will be $C^{32}\ H^{27}\ Az^{4}\ O^{13}$, differing by an atom of hydrogen in excess and an atom of oxygen deficient. If we adopt Scherer's formula, and compare chondrin with protein we have,

Chondrin,	.	$C^{48}\ H^{40}\ Az^{6}\ C^{20}$
Protein,	.	$C^{48}\ H^{36}\ Az^{6}\ O^{14}$
		$H^{4}\quad O^{6}$, which may be

represented by $4\ (H\ O) + O^{2}$; or two atoms of water and two of oxygen.

We cannot at present explain the cause of the different properties which collin and chondrin possess, though it must be connected with the mode in which the elementary atoms are arranged in each. There can be little doubt that chondrin as well as collin is an amide; but nothing is known respecting the acid, which may be extracted from it, though it is probably the same as that from collin.

It will now be proper to point out the different textures of the animal body which yield collin and chondrin respectively. The subject has been examined with care by J. Müller and Schwann.

1. Skins give collin.
2. Tendons give collin.
3. The cornea of the eye gives chondrin.

4. Elastic membranes; for example the *ligamenta flava* of the falx, the *ligamentum hyothyroideum* and *cricothyroideum medium* of the larynx, the ligaments of the larynx connected with the voice, the middle coat of the arteries, &c. when boiled sufficiently long in water, give a glue possessed of peculiar characters; but approaching nearer chondrin than collin. These membranes have a yellow colour. They consist of fibres full of knots and running into each other. They may be kept for years in alcohol without losing their elasticity.

The glue from them is precipitated by acetic acid and acetate of lead, though not to the same degree as chondrin. It is precipitated also by alum and sulphate of alumina. But persulphate of iron does not occasion a precipitate, it only renders the liquid opal coloured.

5. *Fibrous cartilages*, such as the *cartilaginosi inarticulares*, those of the intervertebral cartilages, those of the eyelids, likewise the semilunar cartilages of the knee-joint of the sheep, give collin.

6. The *spongy cartilages*, viz. the cartilages of the ear, the epiglottis, the appendages to the *cartilagines arytenoideæ* in cattle and swine, give various kinds of gelatin.

That from the cartilages of the ear differs from collin and chondrin in this important respect, it does not gelatinize. The glue obtained by boiling the sound of the cod also refuses to gelatinize, but dries into a hard brown substance, which may be employed to glue pieces of wood together. In chemical properties the glue from spongy cartilages agrees with chondrin, excepting that it is scarcely precipitated by acetic acid.

7. Permanent cartilages, such as those that attach the ribs to the sternum or to each other, the cartilages of the joints, &c. yield chrondrin.

8. The cartilages of bones, obtained by removing the bone-earth by an acid, yield collin. A great many were examined by Müller, and all yielded collin. Yet the same cartilages before ossification has taken place yield *chondrin*. It appears from this that during ossification a change in the cartilaginous structure takes place. What this change is we have at present no notion.

9. Permanent cartilages ossified by disease, yield collin.

10. The cartilages of the teeth yield collin.

11. Fungous bones yield chondrin.

12. Bones softened by osteomalacea yield neither collin nor chondrin. When such bones are long boiled in water we obtain an extract which is quite liquid, and does not gelatinize. When filtered it has a brownish yellow colour. It is precipitated by tannin and alcohol, but not by acetic acid, acetate of lead, or persulphate of iron. Sulphate of alumina produces very little alteration on it, only a scarcely perceptible precipitate of flocks redissolved by adding an excess of the reagent. Caustic potash ley occasions no precipitate. These remarks apply to the very highest stage of osteomalacea when the bones are quite flexible and feeble.*

SECTION III.—GELATIN FROM SILK.

This is probably the substance described by Roard under the name of *gum*.† Mulder first obtained it in a state of purity in 1836, described its properties, ‡ and subjected it to a chemical analysis. § He obtained it from raw silk in the following manner:

The silk was boiled successively in water till every thing soluble in that liquid was taken up. The aqueous solutions were evaporated to dryness, and the residue was treated with alcohol and ether. What remained after the action of these liquids was digested in hot water. The aqueous solution being evaporated to dryness, the residue was considered as pure gelatin from silk.

It has a yellowish colour, is translucent, brittle, and destitute of taste and smell. It is heavier than water, and is not altered by exposure to the air. When heated in the open air it swells, burns with flame, and leaves a bulky charcoal. When this charcoal is consumed a white ash remains, consisting chiefly of carbonate of soda.

It is soluble in water; but insoluble in alcohol, ether, fat and volatile oils. The aqueous solution is very viscid; it speedily undergoes decomposition, giving out an ammoniacal odour. In concentrated sulphuric acid it dissolves at the common temperature of the atmosphere without any change of colour. When heat is applied the solution becomes black, and gives out a mixed smell of caromel and sulphurous acid. In dilute sulphuric acid

* Muller; Poggendorf's Annalen, xxxviii. 322. † Ann. de Chim. lxv. 60.
‡ Poggendorf's Annalen, xxxvii. 606. § Ibid. xl. 284.

it dissolves when assisted by heat. When this solution is boiled for some time the gelatin is converted into starch sugar. Nitric acid dissolves the gelatin at the ordinary temperature of the atmosphere. When heat is applied deutoxide of azote is given out and oxalic acid formed. In concentrated muriatic acid it dissolves without any change of colour. In phosphoric acid it dissolves, and if the solution be heated it blackens.

The solution in concentrated acetic acid forms when evaporated a thick mass. When we mix it with water, no precipitate falls. But prussiate of potash throws down a fine green precipitate, which is soluble in water.

It dissolves in potash, soda, and ammonia, but is thrown down by acids. The solution in acid is also precipitated by alkalies, but the precipitate is again dissolved by adding an excess of potash. We see from this that the gelatin is insoluble in solutions of neutral salts with alkaline bases. It is soluble by boiling in carbonate of potash. When acetic acid is added to this solution, no disagreeable smell is evolved; nor does the liquid become black when silver is added to it.

When the aqueous solution is concentrated and set aside to cool, it gelatinizes—a white precipitate falls, when the following liquids are added to the aqueous solutions of this gelatin; alcohol, infusion of nut-galls, protonitrate of mercury, diacetate of lead, chloride of tin, chlorine water, bromine. The chloride of gold throws down a yellow precipitate.

The following liquids occasion no precipitate when added to an aqueous solution of gelatin: oxalic acid, acetate of lead, corrosive sublimate, nitrate of silver, nitrate of cobalt, cyanodide of mercury, perchloride of iron, chloride of barium, sulphate of potash, iodide of sodium, sulphohydrate of ammonia, acetate of copper, tartar emetic, borax, persulphate of iron. When iodine is triturated with the aqueous solution of gelatin, no action is perceptible.

It was analyzed by Mulder, who found its constituents (abstracting 5·2 per cent. of ashes),

Carbon,	49·49
Hydrogen,	5·98
Azote,	19·19
Oxygen,	25·34
	100·00

These numbers approach so near those obtained by analyzing isinglass and common collin, that we cannot hesitate to consider it as isomeric with these bodies.

CHAPTER III.

OF HEMATOSIN.

THIS name was given by Chevreul to the colouring matter of blood, which Dr Wells,* as early as 1797, showed to be an animal substance of a peculiar nature. Vauquelin and Brande proposed processes for obtaining it in an isolated state, but they did not succeed in freeing it from the albumen with which, in the crassamentum of blood, it is always united. Berzelius and Engelhart proposed other processes; but what these chemists considered as hematosin was in reality a compound of hematosin and albumen. And as the albumen greatly preponderated in point of quantity, the characters which they assigned to the colouring matter were very nearly those which belonged in reality to albumen.

M. Lecanu, in his thesis published in 1837, has given the following process for obtaining pure hematosin.† Into human blood deprived of its fibrin by agitation with a rod, pour sulphuric acid, drop by drop, till the liquor, which assumes a brown colour, coagulates into a thick magma. Dilute this magma with alcohol, which causes it to contract in bulk. Put the whole into a cloth, and subject it to sufficient pressure to squeeze out the alcohol together with the water formerly contained in the blood. What remains in the cloth has a brown colour. It is to be reduced to small particles, and treated repeatedly with boiling alcohol, (the last portions of which must be acidulated,) till the liquid ceases to assume a red colour.

The alcoholic solutions are left at rest till they are quite cold, and then filtered to separate a quantity of albumen which will have precipitated. The filtered liquid must be saturated with ammonia, and then filtered again to get rid of some sulphate of

* See Phil. Mag. xvi. 154.

† *Etudes Chimiques sur le sang humain*, p. 28.

ammonia, which has precipitated together with a new portion of albumen. The alcohol is now to be distilled off. What remains is hematosin mixed with saline matter, some organic matter and some fat. Let it be successively treated with water, alcohol, and ether till it has been freed from everything soluble in these three liquids. It is now to be digested in alcohol containing about 5 per cent. of liquid ammonia. Filter again, distil off the alcohol, and evaporate the residuum to dryness. Wash what remains with distilled water, and dry it in a gentle heat. It is pure hematosin.*

Hematosin thus obtained possesses the following properties: It is solid, without taste and smell, and of a dirty brown colour, provided it be obtained by the process above detailed; but it has the metallic lustre, and a reddish black colour when obtained by evaporating an ammonico-alcoholic solution over the vapour bath.

It is insoluble in water, alcohol of all strengths, sulphuric ether, acetic ether, whether cold or hot.

Water, alcohol, and acetic ether, containing a very small quantity of caustic ammonia, potash, or soda, dissolve it easily and assume a blood red colour. But these alkalies never loose their alkaline reaction, how great soever the quantity of hematosin may be, which they may have dissolved.

Oil of turpentine and olive oil dissolve it when assisted by heat. The solution has a fine red colour.

Alcohol slightly acidulated with sulphuric or muriatic acid dissolves it readily. The solution is brown, but becomes blood-red when the acids are saturated.

Alcohol of 0·8428, or still better, alcohol of 0·9212, dissolves it when assisted by sulphate of soda. But this salt does not render hematosin soluble in water.

Water throws it down completely from its acidulated alcoholic solution. The precipitate is pure hematosin, and contains no acid. Water does not precipitate it from its ammoniaco-alcoholic solution. When the solution is much diluted and boiled for a long time, the hematosin is altered. It assumes a greenish tint, and becomes insoluble in ammoniated alcohol.

* Lecanu at first gave to the colouring matter of blood freed from albumen, the name of *globulin*. But the observations of Gay Lussac and Serullas induced him to abandon that term and adopt *hematosin*.

When the acidulous alcoholic solution is mixed with a solution of albumen in weak alcohol, and the acid is supersaturated, the whole colouring matter precipitates with the albumen in red flocks, which may be washed repeatedly in ammoniated alcohol, without completely losing its red colour.*

When chlorine is passed through water holding hematosin in suspension, this colouring matter is altered in its nature. White flocks precipitate, which are insoluble in water, but soluble in alcohol; while the liquid contains iron easily discoverable by the usual reagents.

Concentrated sulphuric acid does not dissolve hematosin; but it deprives it of iron, and converts it into a black mass insoluble in ammoniated alcohol and sulphuric acid. Very dilute suphuric acid does not dissolve hematosin; but it deprives it of iron, and partly converts it into a new matter soluble in alcohol and ether. The solutions have a red colour, and contain a good deal of oxide of iron. Concentrated muriatic acid behaves almost exactly like dilute sulphuric acid.

Concentrated nitric acid dissolves it, assuming a brown colour, and quite altering the nature of the hematosin.

Mulder has lately examined the action of chlorine on pure hematosin.† If we pass a current of chlorine gas through a mixture of hematosin and water, the colour immediately disappears, and the hematosin becomes white. The white flocks were collected on a filter and washed with water. On analysis they were found to be a compound of the organic matter of hematosin and chlorous acid. It had lost all its iron, which was found dissolved by muriatic acid in the aqueous solution. The liquid portion contained, besides iron and muriatic acid, a little of the organic matter which is not quite insoluble in that acid.

The flocks being dried at 284°, we found composed of

Carbon,	37·34	or 44 atoms =	33
Hydrogen,	3·01	or 22 atoms =	2·75
Azote,	5·89	or 3 atoms =	5·25
Oxygen,	24·34	or 24 atoms =	24·
Chlorine,	29·42	or 6 atoms =	27·
	100·00		92·00

* It was to this compound of hematosin and albumen that Lecanu gave the name of *globulin*.

† Ann. der Pharm. xxxvi. 79.

This is 1 atom hematosin, . $C^{44} H^{22} Az^3 O^6$
6 atoms chlorous acid, . $6(Ch O^3)$

When triturated with twice its weight of saltpetre, and thrown into a red-hot platinum crucible, it is decomposed. The product of the deflagration dissolves in water with the exception of a little oxide of iron. The solution, when neutralized by nitric acid, contains no sensible quantity of sulphuric or phosphoric acid. Hence it follows that hematosin contains neither sulphur nor phosphorus as constituents.

When hematosin is heated in a retort, it does not melt, but gives out ammonia and an empyreumatic oil, and leaves a brilliant charcoal of small bulk, which, when charred, yields a quantity of peroxide of iron. From 100 parts of hematosin Lecanu, in four successive experiments, extracted ten parts of peroxide of iron. Three of these portions of hematosin were obtained from individuals aged about twenty-nine years, and that of the fourth from an individual of eighty-three years of age. Now ten peroxide is equivalent to seven metallic iron.

It is remarkable that iron is not separated from hematosin by ammonia, potash, or soda; nor is its presence indicated by tannin or prussiate of potash. It is difficult to conceive it to exist in the state of oxide; for if it did no reason can be assigned why it is not acted on by these powerful reagents, which are so capable of detecting the presence of oxide of iron in ordinary cases. Berzelius has suggested that it must exist in hematosin in the metallic state. If we were to adopt this opinion, it would follow as a consequence that the red colour of blood cannot be owing to the iron which it contains.

Hitherto hematosin and albumen have been considered as substances possessing very nearly the same properties; doubtless, because the hematosin hitherto examined contained a notable quantity of albumen. The following table, drawn up by M. Lecanu, exhibits the differences between the two in a very striking point of view:

Albumen.	Hematosin.
Colourless, dull.	Black, lustre metallic.
Soluble in water, unless coagulated.	Insoluble in water.
Scarcely soluble in ammonia, slightly in weak potash ley.	Very soluble in ammonia and potash, to which it gives a blood-red colour.

Albumen.	Hematosin.
Insoluble in alcohol and acetic ether, ammoniated or mixed with sulphuric, muriatic, or acetic acids.	Very soluble in alcohol and acetic ether ammoniated or mixed with sulphuric, muriatic, or acetic acid.
Soluble in acetic acid, and in weak muriatic and sulphuric acids, when assisted by heat.	Insoluble in acetic, muriatic, and sulphuric acids, whether weak or concentrated.

Lecanu examined hematosin from human blood, and from that of the ox, domestic fowl, duck, frog, carp, and mackerel, and found it in all cases possessed of the very same properties. The only difference observed was in the proportion of peroxide of iron left when the hematosin was incinerated. Human hematosin left 10 per cent., that of the ox left 12·76 per cent., while that of the domestic fowl left 8·34 per cent.

It seems not unlikely that the yellow, blue, and brown colouring matters obtained by M. Sansen from blood, were hematosin altered by the processes to which he had subjected it. His red colouring matter evidently contained albumen.*

Hematosin was subjected to an ultimate analysis by Mulder, by means of oxide of copper.† He obtained from the hematosin taken from the arterial blood of oxen and sheep,

Carbon,	64·57
Hydrogen,	5·25
Azote,	10·54
Iron,	6·67
Oxygen,	12·97
	100·00

If we suppose the iron to amount to one atom, the constituents of hematosin will be,

43 atoms carbon,	= 32·25	or per cent.	64·89
21 atoms hydrogen,	= 2·625	...	5·29
3 atoms azote,	= 5·25	...	10·70
1 atom iron,	= 3·50	...	7·03
6 atoms oxygen,	6·00	...	12·09
	49·625		100·00

Mulder, to ascertain the atomic weight of hematosin, dried it at the temperature of 266°, and passed a current of chlorine gas over it till it refused to absorb any more. Nothing whatever

* Jour de Pharmacie, xxi. 420. † Annalen de Pharm. xxxi. 134.

separated. The hematosin acquired a dark-green colour. He obtained a compound of

Hematosin,	.	66·19 or 8·78
Chlorine,	.	33·87 or 4·5
		100·00

Now, if we suppose with Mulder that six atoms of chlorine have combined with one atom of hematosin, the atomic weight of this last substance must be 52·68, which approaches, though not very nearly, to 49·625, the weight deduced from Mulder's analysis.

Mulder has again repeated this analysis, and now considers hematosin to be composed of C^{44} H^{22} Az^{3} $O^{6}Fe$ = 50·5.*

The compound of chlorine and hematosin is deep-green. It dissolves in alcohol, communicating to that liquid the colour of bile. Neither acids nor alkalies alter the colour of this solution. But when boiled with potash, it becomes straw-yellow. When heated with sulphohydrate of ammonia, the alcoholic solution becomes red.

Mulder did not succeed in combining iodine in definite quantity with hematosin. When the compound was heated to 302°, a temperature necessary to drive off the excess of iodine, the whole of that substance escaped; however, the hematosin was altered, for it was insoluble in alcohol, mixed with ammonia or with sulphuric acid.

When phosphorus or sulphate of iron is boiled with a solution of hematosin, the colour is not altered. Boiling hot sulphuric acid becomes coloured when mixed with hematosin; but the greatest part of this last substance remains undissolved; yet its nature is altered, for it is no longer dissolved when alcohol is added. When sulphurous acid gas is passed through a solution of hematosin in alcohol, acidulated with sulphuric acid, the colour is not altered; but when the solvent is ammoniated alcohol, the colour becomes light-red.

When hematosin, dried at 266°, is put into dry muriatic acid gas it assumes a violet red colour. The muriate formed dissolves in alcohol, and the liquid assumes a fine red colour. It reacts as an acid. Mulder found that 100 parts of hematosin absorbed 12·97 of muriatic acid. But when the compound was

* Ann. der Pharm. xxxi. 134, and xxxvi. 79.

heated to 212°, 100 hematosin only retained 6.63 of muriatic acid. Hence the first was composed of,

Hematosin, .	49.625 or 52.68	
Muriatic acid,	6·436 or ·6·863	

and the second of,

Hematosin, .	49·625 or 52·68
Muriatic acid,	3·29 or 3·493

The quantity of acid in the first compound was twice as great as in the second. The first compound (if we reckon the atom of hematosin 52·68) is composed of,

1 atom hematosin, .	52·68
1½ atom muriatic acid,	6·9375

The second compound retains only three-fourths of an atom of muriatic acid united to an atom of hematosin.

Hematosin combines with the metallic oxides as well as with acids in definite proportions. Nitrate of silver being mixed with an ammoniacal alcoholic solution of hematosin, and a little nitric acid added, a dark brown precipitate falls. The filtered solution is colourless, and neither contains iron nor colouring matter, the precipitate is a compound of hematosin and oxide of silver. 135 hematosin gave 22·55 of a mixture of 5·15 oxide of silver, and 4·684 peroxide of iron. This compound is black, has a glistening lustre, and burns like hematosin.

It combines in various proportions with oxides of copper and lead. These compounds may be formed in the same way as that of hematosin and oxide of iron.

From the preceding statement it appears that hematosin is capable of combining in definite proportions, both with acids and bases, though it does not neutralize either the one set of bodies or the other.

Lecanu, as has been already stated, extracted 12·67 per cent. of oxide of iron from ox blood. Mulder from the blood of oxen and sheep, only obtained 9·6 per cent.

Mulder has some speculations respecting the difference of hematosin in arterial and venous blood. He thinks it possible that arterial hematosin may be, $C^{43}\ H^{21}\ Az^{3}\ O^{6} + Fe$
and venous, . $C^{43}\ H^{21}\ Az^{3}\ O^{6} + Fe\ C$
and that this carburet of iron is decomposed into iron and carbonic acid by the oxygen absorbed in the lungs.

CHAPTER IV.

OF SPERMATIN.

This name has been given to what is considered as the essential part of human semen. When emitted it is a translucent substance, swelled up, and having much the appearance of mucus, only thicker, and frequently in cylindrical concretions. At first it is insoluble in water: but after a certain time it becomes spontaneously liquid, and then dissolves or mixes readily with water. This remarkable property distinguishes it from all other animal substances.

When semen, at the instant of its emission, is let fall into alcohol of the specific gravity 0·833, it becomes opal coloured, it coagulates into a clot resembling a clue of pack-thread; as if the spermatin consisted of a long thread which had rolled upon itself in passing through the canal of the urethra. Thus coagulated by alcohol it loses the property of liquefying by standing. When dried it remains thready as before, has a snow white colour, and is opaque. In water it gradually softens and assumes the appearance of mucus, especially when boiled in that liquid; but very little of it dissolves. When the water in which it has been boiled is evaporated to dryness, a white opaque matter remains; one portion of which is soluble in cold, and the remainder only in boiling water. Both solutions are abundantly precipitated by infusion of nut-galls. The portion of spermatin not dissolved by the boiling water is equally insoluble in a weak solution of caustic potash.

Spermatin coagulated by alcohol is soluble in cold sulphuric acid, to which it gives a yellow colour. Water throws down the portion dissolved white; and the portion not dissolved contracts when water is added and abandons the acid. The precipitate is insoluble in water, even when assisted by heat.

Nitric acid while cold gives a yellow colour to spermatin, but does not dissolve it; when assisted by heat a solution takes place, but the spermatin is again precipitated by the addition of water. In concentrated acetic acid spermatin becomes gelatinous and translucent. When the acid is raised to the boiling temperature solution takes place; but the liquid still continues muddy, from small undissolved threads remaining interspersed through

it. The solution is precipitated by prussiate of potash; but not by carbonate of ammonia nor corrosive sublimate. It is precipitated also by infusion of nut-galls.

Spermatin coagulated by alcohol is softened in a concentrated solution of caustic potash, but not dissolved, unless the action be assisted by heat. The solution is not precipitated by acetic acid. But if we supersaturate the liquid with this acid, evaporate to dryness, and wash out the acetate of potash with alcohol, the animal matter remains undissolved. Water only dissolves it partially, and the solution is precipitated by corrosive sublimate and infusion of nut-galls.

The alcohol in which semen has been coagulated has an opal tinge, and does not filter clear. When evaporated to dryness, it leaves a residue which has the same properties as that left by water in which the semen has coagulated.

When the semen falls into water at the instant of its emission, it coagulates pretty much as in alcohol, constituting a white fibrous mass, which, on the least touch, separates into threads, and when taken out of the water, dissolves in acetic acid. The solution is copiously precipitated by prussiate of potash. If these filaments are left in water, they gradually dissolve and disappear except a few threads, which subside very slowly. When these are separated by the filter and the watery solution evaporated, it exhales for a long time the peculiar smell of semen, becomes opal-coloured, and when evaporated to dryness, leaves a transparent varnish, scarcely visible, at the bottom of the vessel. Water softens this varnish, and dissolves a little of it, which gives it a yellow colour. When we evaporate this solution and treat the residue with absolute alcohol, a portion is dissolved, which, when freed from alcohol, has the form of a yellow extract, which reddens litmus-paper.

Cold water dissolves very little of the matter on which the alcohol does not act. But boiling water takes up more, and leaves a yellowish-brown and very mucous matter. The aqueous solutions, whether hot or cold, have the same properties. When evaporated to dryness, they leave a yellowish transparent matter, having the smell of toasted bread and a peculiar taste. Water makes it white and mucous, and dissolves it rapidly. The solution is precipitated by acetate of lead, protochloride of tin, corrosive sublimate, nitrate of silver, and infusion of nut-galls.

The portion insoluble in boiling water is not dissolved by acetic acid. It is partially dissolved in cold potash ley.*

CHAPTER V.

OF SALIVIN.

SALIVIN or *ptyalin*, as it is also called, is a peculiar substance which exists in human saliva. It seems to have been first noticed by Dr Bostock in 1805, who describes it under the name of *pure mucus*.† It is not described by Berzelius in the second volume of his Djurkemien, published in 1808. But in his paper on the *Chemical Properties of Animal Fluids*, published in 1813, it is particularly noticed under the name *Salivary, or peculiar Animal Matter*.‡ More lately its properties have been examined by Tiedemann and L. Gmelin.§ Salivin may be obtained in the following manner:

Evaporate saliva to dryness in a gentle heat. Digest the residual mass in rectified spirits, which dissolve most of the salts of saliva. An additional portion of alcohol acidulated with acetic acid will remove any soda that might still remain. Nothing now remains but a mixture of salivin and mucus. Water dissolves the former of these substances, and leaves the mucus. The aqueous solutions being evaporated in a gentle heat, leaves pure salivin.

Thus obtained it is a transparent white substance, which does not crystallize, and is destitute of taste and smell. It is not altered by exposure to the air. It dissolves readily in water, but is insoluble in alcohol. The aqueous solution is not precipitated by alkalies or acids, nor by solutions of diacetate of lead,‖ corrosive sublimate, or of tannin. It does not become turbid on boiling, and does not gelatinize when the concentrated solution is allowed to cool. The only substances which precipitate it from its aqueous solution are alcohol and nitrate of silver. And this

* Berzelius, Traité de Chimie, vii. 558.

† Nicholson's Jour. ii. 251. ‡ Annals of Philosophy, (1st series,) ii. 380.

§ Recherches Experimentales, i. 12.

‖ Bostock obtained a precipitate with this salt because his salivin contained uncombined soda.

last precipitate is soluble in ammonia. Salivin is not precipitated by chlorine.

When salivin is charred, ammonia is given off, and the coal contains potash and soda.

Salivin from neutral saliva does not act as an alkali, but slightly as an acid. If the saliva be not previously neutralized, reddened litmus-paper, when dipt into it, becomes blue. The colour of the salivin is yellowish-brown when the alkali of the saliva is not neutralized, and it absorbs moisture from the air.

CHAPTER VI.

OF PEPSIN.

This name, (from πεψις, digestion,) was given by Dr Schwann of Berlin* to a substance which constitutes an essential portion of the gastric juice, as without its action many articles of food could not be converted into chyme in the stomach. All articles of food containing coagulated albumen, fibrin, and (to a certain extent also) casein.† To make an artificial gastric juice capable of dissolving these substances, the inner coats of the third and fourth stomachs of an ox were digested for twenty-four hours in water containing a mixture of 2¾ per cent. of muriatic acid of commerce. After this digestion (without heat) the liquor was filtered. It contained in solution 2·75 per cent. of solid matter, and required rather more than 2 per cent. of carbonate of potash to neutralize it. When this liquor was digested for several hours on coagulated albumen, (at the temperature of 98°,) in powder, it dissolved it completely.

Muller's experiments showed that the mere acid solution will not dissolve coagulated albumen; and Eberle and Schwann found that the same acid solution, after the ox's stomach was digested in it, has acquired the property of dissolving albumen. Hence something is taken up from these stomachs which gives the acid liquid the property of dissolving albumen and fibrin. It is to this something that the name of *pepsin* has been given.

The following are the facts respecting this principle which

* Poggendorf's Annalen, xxxviii. 358.

† The *chymosin* of Deschamps is obviously the same with pepsin. See Jour. de Pharm. xxvi. 412.

have been determined, and for which we are chiefly indebted to Dr Schwann:

1. When the pepsin solution is neutralized by potash, nothing is precipitated; but its digesting properties are destroyed.

2. Though the pepsin solution be much diluted with acidulated water, its digesting powers are not injured, but it cannot be diluted with pure water without the destruction of these powers.

3. The quantity of acid necessary for the digestive properties of the liquid continuing, is regulated not by the pepsin present, but by the water. The muriatic acid of commerce present must amount to $2\frac{3}{4}$ per cent.

4. When food is dissolved in this acidulated liquor, none of the acid is saturated. The quantity still uncombined is the same as at first.

5. If we neutralize the solution, evaporate it to dryness in a low temperature, and digest the residue in alcohol, the digestive properties are destroyed.

6. If the pepsin liquor be heated to the boiling point, its digestive properties are destroyed.

7. When acetate of lead is dropt into the pepsin solution, the pepsin is precipitated in combination with the oxide of lead, and the precipitation is more complete if the liquor has been previously neutralized. Pepsin is precipitated also from its neutral solution by corrosive sublimate, but not by prussiate of potash.

8. But the most characteristic action of pepsin is its coagulating milk, and throwing down the casein. When one part of pepsin solution is mixed with 238 parts of milk, the whole is coagulated. The quantity of muriatic acid of commerce necessary to produce the same effect is 3·3 per cent.

The neutralized pepsin solution still coagulates milk, but if its temperature be raised to the boiling point, this property is destroyed.

9. Pepsin and casein may be reciprocally used as reagents for each other. A liquid containing only 0·0625 per cent. of casein is precipitated by the neutral pepsin solutions. This delicate action on casein is the most characteristic property of pepsin hitherto observed, and puts it in our power to distinguish it from other substances, especially from mucus, with which, from some of its properties, it might otherwise be confounded.

10. The small quantity of pepsin which causes the solution of

albumen is remarkable. Acidulated water, holding in solution only 0·25 per cent. of pepsin, shows a decided action on albumen. 98 grains of water acidulated with muriatic acid, and containing only 4·8 grains of the solution of pepsin, dissolves 49 grains of albumen in twenty-four hours at the temperature of 99°.5. Now as 4·8 grains of the digesting liquor contain only 0·11 grain of solid matter, it follows that one grain of pepsin is capable of causing the solution of at least 100 grains of dry albumen.

11. When pepsin liquor is employed to dissolve albumen, it partly loses its digestive power. Hence it must suffer an alteration during the process.

12. It acts best at the temperature of 100°, but it will act also at 54° or 55°, though not so well.

M. Wasmann has succeeded in obtaining pepsin in an isolated state by the following process:* He separates the glandular membrane of the stomach without cutting it, washes it, and digests it in distilled water at a temperature between 86° and 95°. After several hours, he decants off the liquid, and washes the membrane again in cold water till it gives out a putrid smell. The waters are mixed and filtered. The liquid thus obtained is transparent, a little viscid, and possessed of a strong digestive power, when a little muriatic acid is added to it. To separate pure pepsin from it, acetate of lead is added, the precipitate washed, mixed with water, and decomposed by sulphuretted hydrogen. The liquid separated anew is fluid, colourless, and acid. When, after having evaporated that liquid to the consistence of a syrup, in a temperature which must not exceed 95°, we pour absolute alcohol into it, a copious flocky precipitate falls, which, being carefully dried, is a yellow gum-like substance, which does not attract moisture from the atmosphere.

Pepsin is soluble in water, which it makes acid, because it retains obstinately a little acetic acid. The solution, though it contained no more than $\frac{1}{5000}$th of pepsin, dissolves in six or eight hours white of egg slightly acidulated: but it loses its digestive properties when boiled or saturated with potash. In the last case, it deposites flocks which are insoluble in water, but dissolve slowly in dilute acids, constituting feebly digestive liquids.

We recognize pepsin by the precipitates thrown down by di-

* Jour. de Pharm. xxvi. 481.

lute acids from its solution, and which are again redissolved by an excess of the acids. It is distinguished from albumen by the precipitates produced by acetic acid and muriatic acid in its aqueous solutions; and from casein, because prussiate of potash does not precipitate its acid solutions.

A concentrated solution of pepsin is thrown down by corrosive sublimate and acetate of lead, but the precipitates are redissolved by adding an excess of the reagent, and also by acetic and muriatic acids. The sulphates of iron and the protochloride of tin also precipitate pepsin; and all the precipitates by metallic solutions possess digestive properties.

When burning, pepsin gives out the odour of burning horn, and leaves a charcoal difficult to incinerate, in which is found lime, soda, phosphoric acid, and a little iron.

CHAPTER VII.

OF PANCREATIN.

This substance was detected in the pancreatic juice of the dog by Tiedemann and L. Gmelin, but they did not obtain it in a separate state. The only characteristic property of it which they ascertained is this: it is coloured red by a small quantity of chlorine, and discoloured by a small quantity.

DIVISION II.

OF THE PARTS OF ANIMALS.

The different substances which compose the bodies of animals may be divided into two classes, namely, 1*st*, the *solid parts*, such as bones, muscles, skin, &c. of which their bodies are made up; 2*d*, the *fluid parts*. Some of these, as the *chyle* and *blood*, are intended for the nourishment of the living being; others, as *sa-*

liva and *bile*, are secreted to answer important purposes in the animal economy; others, as the *urine*, are separated from the blood to be thrown out of the body as useless to the system; and others, as *milk*, for the nourishment of the young animals. To these may be added certain foreign substances which make their appearance in various parts of the body in consequence of disease. These being usually solid bodies have received the name of *morbid concretions*. This important division will therefore be divided into three parts, namely, 1. The Solid Parts of Animals; 2. The Liquid Parts; and 3. Morbid Concretions.

PART I.

OF THE SOLID PARTS OF ANIMALS.

The solid parts of animals are very numerous, and many of them hitherto have scarcely been examined. The following chapters contain a general view of such of them as have hitherto come under chemical investigation.

CHAPTER I.

OF BONES.

By *bones* are meant those hard, solid, well-known parts to which the firmness, strength, and shape of living animals are in some measure owing. In man, quadrupeds, and most other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but in some of the tribes of the lower animals, as the *Conchifera* and *Mollusca*, the bony portion is placed on the outside of their bodies, evidently for defence. In this case, they are distinguished by the name of *shells*. In other animals, as *lobsters* and *crabs*, the external bony covering is called *a crust*. We shall treat of bones in the present chapter, and of shells, crusts, and zoophytes afterwards.

The bones in a human skeleton of mature age amount to about 200, not reckoning the teeth; but in extreme youth they are

more numerous; because various bones, at first separate, gradually unite into one as the age of the individuals advances. They are very various in their shape. Some, as the shoulder-bone, the thigh-bone, &c. are long and hollow; others, as those of the cranium, are flat and thin; while others, as those of the wrist and heel, are short and solid, or nearly so. They are covered by an external membrane, which adheres to them closely, and called the *periosteum*. The external cavity of the long bones is also lined with a periosteum, from which many of the vessels destined to nourish the bones originate. The flat bones are hard and dense at the surface, but interiorly they have a kind of cavity divided into innumerable cells by means of thin bony partitions.

When bones are stripped of their periosteum by long boiling, they are white, if from a healthy animal. When the animal has been diseased, the bones frequently have a shade of yellow. The specific gravity varies a little: that of the blade-bone or scapula of an ox is 1·656, as determined by Mr John Caswell.*

The following little table exhibits the specific gravity of various bones as determined by me:

Os femoris of a sheep,	2·0345
Tibia of sheep,	2·0329
Ileum of an ox,	1·8353
Human os humeri,	1·7479
Vertebræ of haddock,	1·6350
First phalanx of human great toe,	0·9775

As the age of these bones was unknown, it is impossible to draw any general inference from these experiments. The lightness of the bone of the great toe was obviously owing to the cavity within. When boiled in water, they do not lose their shape, but a quantity of collin is separated, and likewise a portion of fatty matter. Alcohol and ether, when digested on bones, also dissolve a quantity of fatty matter. When left in contact with muriatic acid the earthy matter of bones dissolves, and a cartilage remains, soft and flexible, but retaining nearly the shape and bulk of the original bone. When this cartilage is boiled for a long time in water, it is dissolved and converted into collin, with the exception of a small portion of fibrous-looking matter, which still

* Phil. Trans. 1693, xvii. 694.

remains, and which Berzelius assures us consists of the small blood-vessels which traversed the bone in order to supply it with nourishment.

The fact that muriatic acid deprives bones of their earthy matter, leaving only cartilage, was not unknown to chemists at an early period. It is mentioned by Boerhaave as well-known in his time.* It had also been long observed that when bones are heated in an open fire they burn with flame, and leave a white, brittle, friable substance, having the shape of the original bone, but much lighter, and distinguished by the name of *earth of bones*. In some of the earlier systems of chemistry, the *earth of bones* is considered as a substance *sui generis*, and ranked among the earths. About the year 1768, Assessor Gahn of Fahlun discovered that this supposed earth consisted chiefly of *phosphate of lime*. Scheele, in his experiments on *fluor spar*, published in 1771, mentions, when giving an account of the action of phosphoric acid on fluor spar, that it had been lately discovered that the earth of bones was phosphate of lime.† In consequence of this notice, it was for some time believed that Scheele was the discoverer of the constitution of bone-earth; and Assessor Gahn was so indifferent about his reputation as a discoverer, that he never tried to correct a mistake, which had been so long prevalent.

The first person that attempted an analysis of bone was Merat-Guillot, an apothecary at Auxerre, who, about the year 1798, published a comparative analysis of the bones of man, and of a variety of other animals;‡ but his results were far from near approximations to the truth. About the year 1801, Fourcroy and Vauquelin announced the discovery of phosphate of magnesia in bones, and published an analysis of the bones of an ox.§ In 1808, Berzelius published the second volume of his Animal Chemistry, in which he gave an analysis both of human bone and that of the ox.|| Morichini had announced a year or two before that fossil bones contained fluoric acid in combination with lime, and this discovery was confirmed by the experiments of Gay-Lussac.¶ Berzelius, in his elaborate analysis of

* Boerhaave's Chemistry, i. 518; English translation.
† Scheele's Essays, p. 13; English translation.
‡ Ann. de Chim. xxxiv. 68. § Ibid. xlvii. 244.
|| Djurkemie, ii. 120. ¶ Phil. Mag. xxiii. 264, or Ann. de Chim. lv. 258.

bones, published in 1806,* announced the existence of fluate of lime in fresh bones; but this discovery has not been verified by other experimenters. Dr Wollaston tried in vain to extract fluoric acid from recent bones; and unless I have been misinformed the same want of success attended the researches of Mr Brande upon the same subject. In 1829, M. Denis published a comparative analysis of human bones from subjects of very different ages.† About the same time, M. D'Arcet pointed out the quantity of nourishment which bones contain, and the best method of extracting it.‡ The investigations of Muller in 1836, on the structure and chemical properties of the animal matter in bones and cartilages,§ have added considerably to our knowledge of a set of bodies highly worthy of a more accurate and complete investigation than they have hitherto met with.

1. If we leave a bone in dilute muriatic acid at the common temperature of the atmosphere, the earthy salts are gradually dissolved, and the acid may be removed by keeping the bone for some time in water, which must be renewed till it comes off from the solid residue of the bone quite tasteless. What remains is now the *cartilage*. It has the size and shape of the original bone; but is soft, elastic, and translucent, and has a yellowish white colour. When dried the cartilage diminishes somewhat in bulk, though it retains its translucency. It is hard and brittle, and assumes very much the appearance of horn.

From the microscopic observations of Purkinje and Deutsch,‖ it appears that when the cartilage from a long bone is examined it consists of a congeries of long minute tubes filled with marrow. These tubes, according to Muller, consist of very fine circular plates, and the intervals between them are filled up by numerous circular plates which encircle the tubes. These plates may be separated from each other by macerating the cartilage for a long time in water. Besides these marrow tubes the cartilage contains numerous scattered oval-shaped particles, the length of which varies from 0·0004 to 0·0006 inch, and their breadth from 0·00014 to 0·00025 inch, according to the measurement of Miescher. These particles usually lie so that their length is

* Afhandlingar, i. 195.
† Jour. de Physiologie, ix. 183.
‡ Jour. de Pharmacie, xv. 236.
§ Poggendorf's Annalen, xxxviii. 295.
‖ Müller, Poggendorf's Annalen, xxxviii. 296.

parallel to that of the marrow tubes. They are rather more opaque than the concentric plates which surround the marrow tubes. Whether they be solid or perforated has not been determined. In the cartilages of the ribs these particles are very irregular in their position.

The weight of cartilage in the long bones varies from 28 to 33⅓ per cent. It is very difficult to prevent a portion of it from being dissolved by the muriatic acid employed to remove the earthy salts of the bone. The best way is to take care that the acid be very dilute. When the cartilages of bones are boiled a sufficient time in water they are converted into *collin*, while the permanent cartilages of the body by the same treatment become *chondrin*. It is obvious from this that there is a difference between the cartilages of bones and the permanent cartilages, though in what that difference consists we cannot at present specify. It has been already stated, on the authority of Berzelius, that when the cartilage is thus converted into collin or chondrin the blood-vessels of the bones remain undissolved, and fall to the bottom of the liquid under the form of delicate fibres.

2. The other constituent of bone is the earthy salts, which are gradually deposited in the cartilage as the age of the animal advances. The bones of the fœtus, at a certain interval before birth, are all cartilage. At birth they are partly bone and partly cartilage. The ossification goes on progressively, and in old age only those permanent cartilages retain their nature which are necessary for the maintenance of life and motion; as the cartilages of the ribs and those that tip the articulating bones.

The earthy salts are held in solution by the muriatic acid. From the effervescence which attends the action of muriatic acid on bones, it is obvious that one of these salts is a carbonate. And as calcined bones contain carbonate of lime, there is no reason to doubt that carbonate of lime constitutes one of the earthy salts which exists in bones.

If we saturate the muriatic acid solution with caustic ammonia, adding an excess of that alkali, the phosphate of lime precipitates and may be collected on the filter. It constitutes more than one-half of the weight of the bone subjected to analysis.

If we now add carbonate of ammonia to the liquid which has

passed through the filter, the carbonate of lime will be thrown down, and may be collected on a filter. The liquid still contains magnesia, which was prevented from falling by the excess of ammonia used, or rather of sal-ammoniac formed, which, constituting with the magnesia a double salt, prevented it from falling down when the carbonate of ammonia was added.

Let the residual liquid be evaporated to dryness and the residue exposed to a strong heat. The magnesia will remain nearly pure. But it is mixed with a little common salt. Water dissolves the common salt and leaves the magnesia. In this way may all the constituents of the earth of bones be separated from each other. They consist of

Subsesquiphosphate of lime,
Carbonate of lime,
Magnesia,*
Common salt,

Probably the common salt in the bone may have been partly in the state of soda.

Berzelius analyzed human and ox bones, having first deprived them of all the fatty matter or marrow which they contained, and also having freed them from their periosteum. The following are the results which he obtained:

	Human.	Ox.
Cartilage soluble in water,	32·17	33·30
Vessels, . .	1·13	
Subsesquiphosphate of lime,	53·04	57·35
Carbonate of lime, .	11·30	3·85
Phosphate of lime, .	1·16	2·05
Soda with a very little common salt,	1·20	3·45
	100·00	100·00

From the experiments of Dr Rees,† it appears that the proportion of cartilage and earthy matter differs somewhat in different bones. The following are the proportions in different human bones of an adult:

* The magnesia is not in the state of phosphate, as Fourcroy and Vauquelin supposed; otherwise it would have been precipitated by the caustic ammonia. It may have been in the state of carbonate.

† Medico-Chirurgical Transactions, Vol. xxi.

	Earthy matter.	Cartilage.
Femur,	62·49	37·51
Tibia,	60·01	39·99
Fibula,	60·02	39·98
Humerus,	63·02	36·98
Ulna,	60·50	39·50
Radius,	60·51	39·49
Squamous portion of temporal bone,	63·50	36·50
Vertebra, (arch of dorsal),	57·42	42·58
Rib, (external crust),	57·49	42·51
Clavicle,	57·52	42·48
Ileum, (near the crest),	58·79	41·21
Scapula, (coracoid process),	54·51	45·49
Sternum,	56·00	44·00
Metatarsal bone of great toe,	56·53	43·47

The cancellated structure of various bones gave the following results:

	Earthy matter	Cartilage.
Head of femur,	60·81	39·19
Rib,	83·12	46·88
Solid portion of ditto,	57·77	42·23

Dr Rees examined also the bones of a fœtus, and obtained the following result:

	Earthy matter.	Cartilage.
Femur,	57·51	42·49
Tibia,	56·52	43·48
Fibula,	56·00	44·00
Humerus,	58·08	41·92
Radius,	56·50	43·50
Ulna,	57·49	42·51
Clavicle,	56·75	43·25
Ileum,	58·50	41·51
Scapula,	56·60	43·40
Rib,	57·35	42·65
Parietal bone,	55·90	44·10

The following analyses were made by M. Denis. He does not notice magnesia, but perhaps it may be included in the carbonate of lime:

	Radius of a girl aged 3 years.	Do. of Do. aged 20.	Do. of Do. aged 78.
Water with a little grease,	33·34	13	15·4
Cartilage,	33·34	27·8	27·9
Phosphate of lime,	23·32	53·0	43·9
Carbonate of lime,	10	6·2	12·8
	100·00	100·0	100·0

Ox bones were analyzed by Fourcroy and Vauquelin, who stated their constituents to be,

Cartilage,	51·0
Phosphate of lime,	37·7
Carbonate of lime,	10·0
Phosphate of magnesia,	1·3
	100·0

Lassaigne analyzed the callus of a broken bone with the different sound parts of the bone in its neighbourhood, and obtained the following results:

	Callus; outer side.	Ditto. inner side.	Sound bone.	Ditto. thickened.	Sound part in do.	Exostosis.
Animal matter,	50·0	48.5	40·	43·	41·6	46·
Soluble salt,	11·3	12·8	12·4	14·2	8·6	10·
Carbonate of lime,	5·7	6·2	7·6	6·5	8·2	14·
Phosphate of lime,	33·0	32·5	40·0	36·3	41·6	30.
	100·0	100·0	100·0	100·0	100·0	100·

According to Berzelius's analysis, the proportion of carbonate of lime is much greater in the human bone than in that of the ox. But the analysis of Fourcroy and Vauquelin gives a different result. The following table by Fernandez de Barros shows the relative quantities of phosphate and carbonate of lime found in the ashes of the bones of various animals :*

	Phosphate of lime.	Carbonate of lime.
Lion,	95·	2·5
Sheep,	80·	19·3
Fowl,	88·9	10·4
Frog,	95·2	2·4
Fish,	91·9	5·3

Berzelius analyzed the ashes of human bones, (we do not know of what age,) and found them composed of,

* Berzelius, Traité de Chimie, vii. 475.

	Human.		Ox.
Phosphate of lime,	81·9 }	86·4	90·7
Fluate of lime,	3·0 }		
Lime,	10·0	9·3	1·45
Magnesia,	.	0·3	1·10
Phosphate of magnesia,	1·1		
Soda,	2·0	2·0	3·75
Carbonic acid,	2·0	2·0	3·
	190·0*	100·0	100·0

The loss in the analyses varied from 1 to 1½ per cent. The proportions varied somewhat in different specimens of bone.* It is obvious that the bone ashes had been exposed to so strong a heat as to drive off the carbonic acid from the carbonate of lime. Now 10 lime requires 7·85 carbonic acid to convert it into carbonate. Hence the carbonate of lime must have amounted to 17·85 per cent. From this it appears that the proportion of phosphate of lime to carbonate of lime in human bones approaches pretty nearly to that in sheep bones.

The following table exhibits the results of several analyses of bones made by me:

1. Human thigh bone.

Cartilage,	39·12	35·93
Phosphate of lime,	43·67	51·12
Carbonate of lime,	14·00	9·77
Magnesia,	0·49	0·63
Soda,	2·00	0·59
Potash,	0·06	trace
	99·34	98·04

2. Ileum of a sheep.

Cartilage,	43·30	47·20
Phosphate of lime,	50·58	46·35
Carbonate of lime,	4·49	4·88
Magnesia,	0·86	0·64
Soda,	0·31	2·09
Potash,	0·19	0·25
	99·73	101·41

* Gehlen's Jour. (2d series,) iii. 1; or Afhandlingar, i. 216.

3. Ileum of ox.

Cartilage, .	48·5
Phosphate of lime,	45·2
Carbonate, of lime,	6·1
Magnesia, .	0·24
Soda, . .	0·20
Potash, . .	0·11
	100·35

4. Tibia of a sheep.

Cartilage, .	51·97
Phosphate of lime,	40·42
Carbonate of lime,	7·03
Magnesia, .	0·22
Soda, . .	0·19
Potash, .	trace
	99·83

5. Vertebræ of haddock.

Cartilage, .	39·49
Phosphate of lime,	56·08
Carbonate of lime,	3·57
Magnesia, .	0.79
Soda, .	0·79
	100·72

6. Snout of saw-fish deprived of teeth.

Cartilage, &c.	46·31
Phosphate of lime,	42·55
Carbonate of lime,	2·638
Magnesia, .	0·101
Soda, .	0·141
Water, .	6·920
	98·66

The middle or compact part of the long bones contains but little fatty matter; but the extremities of these bones are cellular or spongy, and contain a great deal. The same remark applies to the extremities of the flat bones. M. D'Arcet, who has

paid great attention to the subject, informs us that these spongy portions of bones are composed of,

Earthy salts, .	60
Cartilage, . .	30
Fatty matter, .	10
	100.*

The blood-vessels and several membranes of the body sometimes ossify. In such cases it would appear from the analysis of an ossified pericardium by Petroz and Robinet, that, instead of cartilage, such ossifications have an albuminous membrane much smaller in quantity than the cartilage of real bones. The result of their analysis was as follows:

Animal membrane, gelatin, and albumen,	24·2
Common salt and sulphate of soda, .	4·0
Carbonate of lime, . .	6·5
Phosphate of lime, . . .	65·3
	100·0†

CHAPTER II.

OF TEETH.

Though the teeth are in fact *bones*, yet, as they contain some substances which do not occur in any other part of the bony structure, they deserve to be described in a separate chapter.

The human teeth in an adult individual amount to 32; 16 being set in each jaw. There are 4 *incisors* or *cutting* teeth in each jaw, placed in the fore-part of the mouth, forming the convex prominent part of the dental arch. They are wedge-shaped; being intended, as the name implies, for cutting the food, that only the quantity capable of being masticated may be taken into the mouth at once.

There are two *canine* teeth in each jaw, one on each side of the incisors. They have a single root like the cutting teeth, but longer, and their crown terminates in a blunt point.

The *bicuspid teeth* or *smaller molars* are four in number in

* Journ. de Pharmacie, xv. 236. † Ibid. ix. 507.

each jaw; two next each incisor. Their roots, as the name implies, terminate near their extremities in two points, and there is a groove from the neck of the tooth to its bicuspid termination. The cutting extremities of the crown present two tubercles, one external, the other internal.

The grinding teeth or *larger molars* are six in number in each jaw, and are farthest back of all the teeth. These teeth in the upper jaw have usually three roots, and in the under jaw two. The upper surface of the crown is flat, but has four tubercles arranged crosswise, in order to triturate the food.

Every tooth is divided by anatomists into the *root*, the *neck*, and the *crown*. The *root*, or the part of the tooth contained within the alveolus, is similar in its nature to common bone; the *neck* is the part of the tooth intermediate between the root and crown, or the portion just in contact with the gums. The *crown* is the part of the tooth projecting into the mouth, and fully in view. The central portion of it is bone, but exteriorly it is encased by a layer of white and very hard laminated substance, called *enamel*. This layer is thick on the upper and lateral parts of the crown, but becomes thinner as it approaches the neck, and disappears altogether in the root.

The teeth of the inferior animals differ in their form and structure from those of man. But a description of them belongs to the comparative anatomist. They are composed of bone and enamel.

The tusks of the elephant have received the name of *ivory*. In consequence of its hardness and compact texture, it is susceptible of a fine polish, and is on that account applied to a great variety of purposes. It is liable, especially East Indian ivory, to become yellow. The tusks of some other animals, as the hippopotamus and walrus, consist also of ivory. Even human teeth contained a portion of ivory. The enamel differs from ivory in containing very little cartilage, while about a third part of the weight of ivory consists of cartilaginous matter.

A tooth consists essentially of four parts.

1. The *pulp* within the cavity of the tooth. It is from it that the whole tooth originates. In process of time this pulp is frequently converted into bone by the deposition of calcareous salts.

2. The *ivory*. This constitutes almost the whole of the tooth. It resembles bone in its composition; but differs from common bone in being harder and denser.

3. The *enamel.* It covers the crown of the tooth as far as the neck. It is very hard, and is obviously intended to prevent the tooth from wearing so fast as it otherwise would do while performing the office of mastication. The enamel has no cartilage, and, consequently, has a higher specific gravity than the ivory of the tooth.

4. The *capsule.* This is a thin double membrane which, before extrusion, covered the whole tooth. It is gradually worn away on the crown; though Mr Nasmyth has frequently found it either entire, or fragments of it on the crown even of an adult tooth.* It remains during life on the roots of the teeth. But it is frequently ossified, and then gets the name of *crusta petrosa.*

Leuwenhoek first observed in 1678, that the body of the tooth is composed of a congeries of transparent tubes, so small, that six or seven hundred of them together do not exceed the size of a human hair.† Purkinje, in his work on the teeth, published in 1835, confirmed this observation of Leuwenhoek. If the calcareous salts be removed by steeping a tooth in dilute muriatic acid, and the cartilage be examined under a sufficiently powerful microscope, it is found, he says, to consist of transparent tubes, running from the centre to the circumference. They are not straight, but curved, and their diameter does not exceed $\frac{1}{800}$th of an English line. They become smaller as they reach the outer surface of the tooth, and seem to terminate in cells. They send out numerous branches, especially towards their external extremity. These tubes, according to Müller, in the tooth, not acted on by muriatic acid, are white and opaque, being filled with the calcareous salts of bone; not in crystals, but in very fine powder usually cohering together. The ivory, it would appear from Retzius's observations, is deposited layer by layer round the surface of the pulp; the most external layer having been first deposited.

The enamel adheres internally to a thin membrane, which long resists water. It consists of hexagonal tubes which proceed from the membrane. ‡

* *On the structure, physiology, and pathology of the tooth.* Medico-Chirurgical Transactions, Vol. xxii.

† Phil. Trans. xii. 1002.

‡ On the structure of the teeth, the reader is referred to an elaborate paper by Retzius, published in the Memoirs of the Stockholm Academy for 1836, and

The following table exhibits the specific gravity of the enamel of various teeth as determined by my trials:

Human temporary tooth,	2·711
Human adult tooth,	2·688
Hippopotamus,	2·750
Elephant,	2·843
Mean,	2·748

The specific gravity of the ivory of various teeth is as follows:

Human temporary tooth,	2·090
Human adult tooth,	2·105
Cryptenopus Capensis,	2·020
Hippopotamus,	1·866
Walrus,	1·888
Mean,	1·994

The specific gravity of the decayed part of a human tooth was 1·533. That of the *crusta petrosa* of an elephant's tooth was 1·892.

The following table exhibits the constituents which I extracted from the enamel of various teeth:

	Hippopotamus.	Elephant molar tooth.	Human adult tooth.	Human temporary tooth.
Animal membrane,	1·307	6·80	19·07	7·84
Subsesquiphosphate of lime,	78·30	81·55	64·84	76·73
Carbonate of lime,	12·09	7·65	2·63	7·67
Magnesia,	3·92	1·65	1·09	4·09
Chloride of potassium,	2·57	1·05	1·49	1·13
Chloride of sodium,			4·13	1·74
Water,	0·98	1·005		
Sand,	0·65	...	0·14	0·63
	99·817	99·705	99·39 *	99·83

entitled *Mikroskopiska undersökningar öfver Tändernes, särdeles Tanbenets struktur*. It contains a very complete history of all that has been done on the subject, together with numerous interesting observations of his own.

When Mr Nasmyth's *Researches on the development, structure, and diseases of the teeth*, at present in the press, make their appearance, we may expect a great deal of new information; as he has been long and assiduously occupied with the anatomy of these organs. His historical introduction already published is very complete, and very interesting and instructive.

* It is obvious from the result of the analysis, that this enamel was not pure,

What is marked sand was in the hippopotamus enamel grains of sand lodged mechanically. In human teeth it was silica, tinged slightly with iron.

The following table exhibits the constituents which I extracted from the ivory of various specimens of teeth subjected to analysis:

	Hippotamus.	Walrus.	Human adult tooth.
Cartilage,	28·87	32·11	25·38
Subsesquiphosphate of lime,	48·30	51·93	54·14
Carbonate of lime,	7·90	2·58	5·76
Magnesia,	1·03	0·94	1·37
Chloride of potassium,	0·30	...	3·02
Chloride of sodium,	...	3·30	
Silica,	...	0·21	0·33
Moisture,	13·09	10·33	10·37
	99·49	101·40	100·37

A carious human tooth, having a specific gravity of 1·533, being subjected to analysis, yielded,

Cartilage,	57·78
Subsesquiphosphate of lime,	30·00
Carbonate of lime,	2·09
Magnesia with trace of silica and peroxide of iron,	2·05
Chloride of potassium,	1·25
Moisture,	9·45
	102·62

The crusta petrosa from an elephant's tooth, having a specific gravity of 1·892, being analyzed, yielded the following constituents:

but contained a good deal of ivory. The animal membrane was at least partly cartilage. The deficiency was occasioned by a portion of the cartilage having been dissolved in the muriatic acid. The specimen examined was in powder. It was impossible to determine whether it was pure enamel by the eye.

Cartilage,	31·05
Subsesquiphosphate of lime,	46·34
Carbonate of lime,	6·32
Magnesia,	2·81
Common salt,	4·21
Water,	10·86
	101·59

It therefore resembles ivory in its composition as it does in its specific gravity. The excess observable in some of the preceding analyses may have been partly owing to the chlorides of potassium and sodium not existing as such in the teeth but only their bases. The analysis threw no light upon this. And I was unable to extract either an alkali or a chloride from the teeth by simply boiling them in water.

Berzelius analyzed the enamel and ivory of different teeth.* The result was as follows:

	Human.	Ox.
Subsesquiphosphate of lime,	88·5	85·0
Carbonate of lime,	8·0	7·1
Phosphate of magnesia,	1·5	3·0
Soda,	...	1.4
Brown membranes, alkali water,	2·0	3·5
	100·0	100·0

His analysis of the ivory of teeth gave the following result:

	Human.	Ox.
Cartilage and vessels,	28·0	21·000
Subsesquiphosphate of lime,	64·3	63·15
Carbonate of lime,	5·3	1·38
Phosphate of magnesia,	1·0	2·07
Soda with some common salt,	1·4	2·40
	100·0	100·00

Lassaigne† published the result of his analysis of the teeth of various animals a good many years ago. He did not separate the enamel from the ivory; but appears to have subjected the

* Traité de Chimie, vii. 479; or Afhandlingar, i. 222.

† Jour. de Pharmacie, vii. 1.

whole tooth to analysis at once. The following table shows his results.

	Animal matter.	Phosphate of lime.	Carbonate of lime.
Tooth of a child aged 1 day,	35	51	14·
Of a child aged 6 years,	28·57	60·01	11·42
Of an adult man,	29	61	10
Of a man aged 80 years,	33	66	1
Of an Egyptian mummy,	29	55·5	15·5
Front teeth of a rabbit,	31·2	59·5	9·3
Molar of a rabbit,	28·4	63·7	7·8
Molar of a rat,	30·6	65·1	5·3
Molar of a boar,	29·4	63	6·8
Tusk of a boar,	26·8	69	4·2
Tusk of hippopotamus,	25·1	72	2·9
Front tooth of a horse,	31·8	58·3	10
Molar of a horse,	29·1	62	8·9
Front tooth of an ox,	28	64	8
Teeth of an orycteropus,	27·3	65·9	6·8
Teeth of a gavial,	30·3	61·6	8·1
Teeth of a viper,	30	76·3	3·2
Poisonous tusks of viper,	21	73·8	5
Teeth of a carp,	28	49	16

Mr Pepys* made some analyses of teeth many years ago, which it will be worth while to state.

From the enamel of the human tooth he obtained,

Phosphate of lime	78
Carbonate of lime,	6
Loss and water,	16
	100

From the ivory of the teeth he got,

	Roots of, the teeth.	Teeth of adults.	Milk teeth.
Phosphate of lime,	58	64	62
Carbonate of lime,	4	6	6
Cartilage,	28	20	20
Loss,	10	10	12
	100	100	100

* Fox on the Teeth, p. 96.

Mr Hatchett examined *fossil bones* from the rock of Gibraltar. He found them to consist of phosphate of lime without any cartilage or soft animal part. Their interstices were filled with carbonate of lime. Hence they resemble exactly bones that have been burnt. They must, then, have been acted upon by some foreign agent; for putrefaction, or lying in the earth, does not soon destroy the cartilaginous part of bones. On putting a human os humeri, brought from Hythe in Kent, and said to have been taken from a Saxon tomb, into muriatic acid, he found the cartilaginous residuum nearly as complete as in a recent bone. From the experiments of Morichini,* Klaproth,† and Fourcroy, and Vauquelin,‡ we learn that fossil ivory and teeth of animals frequently contain a portion of fluate of lime. Morichini and Gay-Lussac endeavoured to prove that this salt existed even in recent ivory, and that the enamel of the teeth was almost entirely composed of it.§ But the experiments of Wollaston, Brande, || Fourcroy, and Vauquelin¶ have shown that there does not exist any sensible portion of fluoric acid in these substances while recent. Berzelius, however, has announced that he separated 3 *per cent.* of fluate of lime from fresh teeth, and that he has detected it also in bones nearly in the same proportion. He even affirms that it exists in urine.**

When the cartilage of teeth is boiled in water it dissolves with the exception of a minute quantity of fibrous matter, which may be the blood-vessels. The solution possesses the characters of collin, not of chondrin.

CHAPTER III.

OF CARTILAGE.

The name *cartilage* is applied to a hard, highly elastic, white substance, often with a pearly lustre, which is attached to or constitutes a part of the texture of bones. The cartilages in the

* Phil. Mag. xxiii. 265.
† Gehlen's Jour. iii. 625.
‡ Phil. Mag. xxv. 265.
§ Ibid. xxiii. 265.
|| Nicholson's Journ. xiii. 216.
¶ Phil. Mag. xxv. 266.
** Gehlen's Journ. vi. 591.

human body may be subdivided into three different sets. 1. Those which at one period of life existed instead of the bones, and which, after the bones are formed, constitute an essential part of the bony texture. These have been already treated of in the last two chapters. 2. Those cartilages which cover the extremities of those bones which constitute moveable articulations, and which are called cartilages of incrustation. These cartilages are covered with a synovial membrane which adds to the polish of their faces. The greater and the more moveable the articulations are to which these cartilages belong, the thicker they are. In old age, these cartilages are occasionally converted into bones. A portion of cartilage tipping the ileum bone of an ox had a specific gravity of 1·1521. 3. The cartilages which unite the ribs to the sternum or to one another, those of the larynx and of the nose, constitute the third set. They are covered by a fibrous membrane called *perichondrium*. They also (if we except those of the nose) frequently ossify in old age.

The facts respecting the structure of cartilages, so far as investigated, have been stated in the preceding chapters. They seem, if we can confide in the microscopic observations of Purkinje, Retzius, and Müller, to consist of a congeries of very minute tubes. When these tubes are filled with calcareous salts the cartilages are converted into bone. It is evident from the diseases to which cartilages are liable that they are supplied with vessels. But in ordinary cases these vessels do not seem to convey red blood; though when inflammation intervenes they may be occasionally seen filled with red blood. And such inflammations may run the same career as in other organs.

In the year 1827, Fromherz and Gugert* analyzed the cartilage of the ribs of a young man, aged 20 years, and found it, after having been dried as completely as possible in the temperature of 212°, composed of,

Animal matter, .	96·598
Salts, .	3·402
	100·000

The salts being subjected to an analysis were found composed of,

* Schweiger's Jour. l. 188.

Carbonate of soda,	35·068
Sulphate of soda,	24·241
Common salt,	8·231
Phosphate of soda,	0·925
Sulphate of potash,	1·200
Carbonate of lime,	18·372
Phosphate of lime,	4·056
Phosphate of magnesia,	6·908
Peroxide of iron and loss,	0·999
	100·000

The animal portion was soluble by long boiling in water, and was converted into gelatin. It has been already stated in a former chapter of this volume, that Müller has shown that gelatin, from the permanent cartilages, differs in its properties from *collin*, or the gelatin from the skin and serous membranes; being precipitated from its solution in water by alum, sulphate of alumina, acetate of lead, and persulphate of iron, which have no action on the aqueous solution of collin. On that account he has distinguished it by the name of *chondrin*. The properties of chondrin, so far as they have been investigated, have been given in a preceding chapter of this volume.

The cartilages of the ribs, those that unite them to the sternum and to each other, give chondrin. Müller found that the cartilages obtained from bones by removing the bone earth, by means of an acid, yielded *collin;* yet the same cartilages before ossification has taken place yield *chondrin.* From this it seems to follow that a change takes place in the nature of the cartilage during the process of ossification.

It is probable that the cartilages of cartilaginous fish would yield chondrin, though I do not know that the experiment has been tried.

The cartilages which cover the extremities of bones destined to move on each other, cannot be converted into collin or chondrin by boiling in water. When deprived of the membrane that covers them, they are much brittler than the cartilages of the ribs. So far as I know, no chemical analysis of such cartilages has been hitherto attempted. Mr Hatchett conceives them to have the properties of coagulated albumen. But this conjecture would require to be verified by actual experiment before it could be admitted as true.

It is well known that many fish instead of bones have cartilages. The cartilaginous dorsal vertebra of the *Squalus cornubiensis* was analyzed by Marchand,* who obtained from it

Animal combustible matter,	57·07
Phosphate of lime,	32·46
Sulphate of lime,	1·87
Carbonate of lime,	2·57
Fluoride of calcium, trace	—
Sulphate of soda,	0·80
Chloride of sodium,	3·00
Phosphate of magnesia,	1·03
Silica, alumina, and loss,	1·20
	100·00

The flat cartilages of the skate gave him,

Animal combustible matter,	78·46
Carbonate of lime,	2·61
Phosphate of lime,	14·20
Sulphate of lime,	0·83
Fluoride of calcium, trace	—
Chloride of sodium,	2·46
Sulphate of soda,	0·70
Phosphate of magnesia and loss,	0·74
	100·00

The translucent cartilages consisted almost entirely of animal matter, as had been previously shown by Chevreul.

CHAPTER IV.

OF MARROW.

THE hollows of the long bones are, in living animals, filled with a peculiar species of fat matter, to which the name of *marrow* has been given. In some bones this matter is a good deal mixed with blood, and has a red colour; in others, as the thigh bones,

* Poggendorf's Annalen, xxxviii. 354.

it is purer, and has a yellow colour. Various experiments on this matter were made by the older chemists, showing it to be analogous to animal fats,* and pointing out some of its peculiarities. Berzelius has examined it in detail, and published the results of his experiments.† The marrow on which his trials were made was obtained from the thigh-bone of an ox.

1. When marrow is digested in cold water it becomes lighter coloured, while the water acquires the colour which it would have received had it been digested on blood. When this water is boiled it becomes muddy, and a dark-brown matter precipitates. This matter consists of coagulated albumen mixed with some phosphate of lime, and phosphate of iron. A small portion of a yellow-coloured salt is dissolved by the action of alcohol or water. This matter, separated from marrow by water, is obviously owing to the blood with which it was mixed. The quantity which Berzelius obtained from marrow amounted to $\frac{1}{100}$th part of the whole. The portion of it dissolved by water and alcohol consisted partly of gelatin and common salt, and partly of the peculiar brown extractive matter obtained by Thouvenel from the muscles of animals, which will be described in a subsequent chapter, when treating of the muscles. The proportion of these substances obtained by Berzelius from marrow amounted to about $\frac{1}{300}$th part of the whole.

2. When marrow is boiled in water, the greatest part of it melts and swims upon the surface of the liquid. The water is at first muddy and milky, but becomes transparent on standing. When passed through the filter, a substance is separated which becomes greyish-green, and semitransparent when dry. More of this matter precipitates when the liquid is evaporated. When the water is evaporated to dryness, a substance is obtained of a sharp aromatic taste like the marrow of roasted meat. These two substances consist chiefly of extractive, gelatin, and a peculiar substance, which approaches the nature of albumen in its properties.

3. When marrow, thus purified, is melted in water and passed through a cloth, a quantity of blood-vessels and skins remain upon the cloth, amounting to about $\frac{1}{100}$th part of the whole.

4. Marrow, thus freed from its impurities, has a white colour with a shade of blue; its taste is insipid and rather sweetish. It

* Neumann's Chemistry, p. 560. † Gehlen's Jour. 2d series, ii. 287.

softens by the heat of the hand, and melts when heated to 113°. When cooled slowly, it crystallizes in sphericles like olive oil. It burns with a flame like tallow. When distilled, it gives first a transparent fluid yellowish oil, accompanied by carbonic acid gas, water, and heavy inflammable air. Afterwards there comes over a white solid oil, accompanied by a less copious evolution of gaseous bodies, and which does not become dark-coloured, as happens when tallow is distilled. This had already been observed by Neumann. This solid oil has a disagreeable smell, amounts to 0·3 of the marrow distilled, reddens vegetable blues, and when boiled in water, gives out a portion of sebacic acid, which Berzelius considered as benzoic acid.

The empyreumatic oil combines readily with alkalies and their carbonates. With the latter it forms a snow-white soap, insoluble in water, though it increases in bulk when placed in contact with that liquid. It combines also with the earths, and forms soaps likewise insoluble in water.

The water which comes over during the distillation of marrow is colourless, has a fetid and sour smell, and an empyreumatic taste. It contains a little acetic acid, empyreumatic oil, and probably sebacic acid; but exhibits no traces of ammonia.

The gaseous products amount to $\frac{1}{10}$th of the marrow distilled. They contain no sulphur nor phosphorus, and consist of carbonic acid and heavy inflammable air, which burns with a white flame, and seems to contain oil in solution.

The charry matter in the retort amounts to 0·05 of the marrow distilled. It is dark-brown, heavy, and brilliant. It is incinerated with difficulty, and leaves an ash consisting of phosphate of lime, carbonate of lime, and some soda.

5. Concentrated sulphuric acid dissolves marrow without the assistance of heat. The solution has the appearance of a brown syrup; and when the acid is diluted with water, the marrow separates unaltered. When heat is applied, the acid decomposes the marrow and forms a resinous coal.

Diluted nitric acid digested on marrow, in a moderate heat, renders it yellow, and gives it more consistence, and the smell of old bones. Concentrated nitric acid dissolves marrow without the assistance of heat, and the marrow is not precipitated by the addition of water.

6. Marrow combines with alkalies and forms soap. Boiling

alcohol and ether dissolve a small portion of it, which precipitates again as the solution cools.

Marrow from the thigh-bone of an ox was found by Berzelius to be composed of the following substances:

Pure marrow,	0·96
Skins and blood-vessels,	0·01
Albumen, Gelatin, Extractive, Peculiar matter, Water,	0·03
	1·00

From the preceding detail it appears, that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature. But it differs considerably in its appearance in different parts of the body, owing chiefly, in all probability, to a greater or smaller mixture of blood.

CHAPTER V.

OF SHELLS.

UNDER the name of *shells* I include all the bony coverings of the different species of shell-fish. For almost all the knowledge of these substances that we possess, we are indebted to the important dissertations of Mr Hatchett. A few detached facts, indeed, had been observed by other chemists; but his experiments gave us a systematic view of the constituents of the whole class.

Shells, like bones, consist of calcareous salts united to a soft animal matter; but in them the lime is united chiefly to carbonic acid, whereas in bones it is united to phosphoric acid. In shells the predominating ingredient is carbonate of lime, whereas in bones it is phosphate of lime. This constitutes the characteristic difference in their composition.

Mr Hatchett has divided shells into two classes. The first are usually of a compact texture, resemble porcelain, and have an enamelled surface, often finely variegated. The shells belonging to this class have been distinguished by the name of *porcela-*

neous shells. To this class belong the various species of *voluta*, *cypræa*, &c. The shells belonging to the second class are usually covered with a strong epidermis, below which lies the shell in layers, and composed entirely of the substance well known by the name of *mother-of-pearl.** They have been distinguished by the name of *mother-of-pearl shells.* The *shell* of the *fresh water muscle*, the *Haliotis iris*, the *Turbo olearius*, are examples of such shells. The shells of the first of these classes contain a very small portion of soft animal matter; those of the second contain a very large proportion. Hence we see that they are extremely different in their composition.

1. Porcelaneous shells, when exposed to a red heat, crackle and lose the colour of their enamelled surface. They emit no smoke or smell; their figure continues unaltered, their colour becomes opaque white, tinged partially with pale-gray. They dissolve when fresh with effervescence in acids, and without leaving any residue; but if they have been burnt, there remains always a little charcoal. The solution is transparent, gives no precipitate with ammonia or acetate of lead; of course, it contains no sensible portion of phosphate or sulphate of lime. Carbonate of ammonia throws down an abundant precipitate of carbonate of lime. Porcelaneous shells, then, consist of carbonate of lime cemented together by a small portion of an animal matter, which is soluble in acids, and therefore resembles gelatin.†

Patellæ from Madeira, examined by Mr Hatchett, were found, like the porcelaneous shells, to consist of carbonate of lime; but when exposed to a red heat, they emitted a smell like horn; and when dissolved in acids, a semiliquid gelatinous matter was left behind. They contain, therefore, less carbonate of lime and more gelatin, which is of a more viscid nature than that of porcelaneous shells.

2. Mother-of-pearl shells, when exposed to a red heat, crackle, blacken, and emit a strong fetid odour. They exfoliate, and become partly dark-grey, partly a fine white. When immersed in acids, they effervesce at first strongly; but gradually more and more feebly, till at last the emission of air-bubbles is scarcely perceptible. The acids take up only lime, and leave a number

* Herissant, Mem. Par. 1766, p. 22. Hatchett, Phil. Trans. 1799, p. 317.
† Hatchett, Phil. Trans. 1799, p. 317.

of thin membranous substances, which still retain the form of the shell. From Mr Hatchett's experiments, we learn that these membranes have the properties of coagulated albumen. Mother-of-pearl shells, then, are composed of alternate layers of coagulated albumen and carbonate of lime, beginning with the epidermis, and ending with the last-formed membrane. The animals which inhabit these shells increase their habitation by the addition of a stratum of carbonate of lime, secured by a new membrane; and as every additional stratum exceeds in extent that which was previously formed, the shell becomes stronger as it becomes larger.*

Oyster shells, according to the analysis of Bucholz and Brandes, are composed of

Albuminous matter,	0·5
Lime,	54·1
Carbonic acid,	44·5
Phosphate of lime,	1·2
Alumina,	0·2
	100·5 †

The scales on the outside of oyster shells, according to the analysis of John, are composed of

Animal matter soluble in water with common salt and trace of phosphates,	3
Ditto insoluble in water,	10
Carbonate of lime,	87
	100 ‡

Though this in general is the structure of the mother-of-pearl shells, yet there is a considerable difference between the proportion of the component parts and the consistency of the albuminous part. Some of them, as the common oyster-shell, approach nearly to the patellæ, the albuminous portion being small, and its consistence nearly gelatinous; while in others, as the *Haliotis iris*, the *Turbo olearius*, the real mother-of-pearl, and a species of fresh-water muscle analyzed by Hatchett, the membranes are distinct, thin, compact, and semitransparent.§ Mother-of-pearl contains

* Hatchett, Phil. Trans. 1799, p. 317.
† Gmelin's Handbuch, ii. 1477.
‡ Chem. Schr. vi. 103.
§ Hatchett, Phil. Trans. 1799, p. 317.

Carbonate of lime,	66
Membrane,	24
	90*

Pearl, a well-known globular concretion, which is formed in some of these shells, resembles them exactly in its structure and composition. It is a beautiful substance of a bluish-white colour, iridescent, and brilliant. It is composed of concentric and alternate coats of thin membrane and carbonate of lime. The iridescence is obviously the consequence of the lamellated structure.†

It is said that the inhabitants of Ceylon have discovered a very remarkable way of bleaching pearls that have become yellow. They mix them with the seeds mingled with earth, with which they feed their fowls; the birds swallow the pearls; the stomach is opened in one or two minutes after, and the pearls are found perfectly bleached. Were they left too long in the stomach, they would doubtless be dissolved.‡ If this statement be true, might not the pearls be bleached by steeping them in a very dilute muriatic acid for a minute or two.

Mr Hatchett found that what is called the *bone* of the *cuttle fish* is exactly similar to mother-of-pearl shells in its composition.

From the comparative analysis of shells and bones, Mr Hatchett was induced to compare them together, and has shown that porcelaneous shells bear a striking resemblance to enamel of teeth; while mother-of-pearl shells bear the same resemblance to the substance of teeth or bone; with this difference, that in enamel and bone the earthy salt is phosphate of lime, whereas in shells it is pure carbonate of lime.

* Merat-Guillot, Ann. de Chim. xxiv. 71.

† Hatchett, Phil. Trans. 1799. ‡ Jour de Pharmacie, xi. 175.

CHAPTER VI.

OF CRUSTS.

By crusts we understand those bony coverings of which the whole external surface of crabs, lobsters, and other similar sea animals are composed. Mr Hatchett found them composed of three ingredients: 1. A cartilaginous substance, possessing the properties of coagulated albumen; 2. Carbonate of lime; 3. Phosphate of lime. By the presence of this last substance they are essentially distinguished from shells, and by the great excess of carbonate of lime above the phosphate they are equally distinguished from bones. Thus the crusts lie intermediate between bones and shells, partaking of the properties and constitution of each. The shells of the eggs of fowls must be referred likewise to the class of crusts, since they contain both phosphate and carbonate of lime. The animal cement in them, however, is much smaller in quantity. From the experiments of Berniard and Hatchett, it is extremely probable that the shells of snails are composed likewise of the same ingredients, phosphate of lime having been detected in them by these chemists.

Mr Hatchett examined the crusts of crabs, lobsters, prawns, and cray fish. When immersed in diluted nitric acid these crusts effervesced a little, and gradually assumed the form of a yellowish-white soft elastic cartilage, retaining the form of the crust. The solution yielded a precipitate to acetate of lead, and ammonia threw down phosphate of lime. Carbonate of ammonia threw down a much more copious precipitate of carbonate of lime. On examining the crust which covers different species of *echini*, Mr Hatchett found it to correspond with the other crusts in its composition. Some species of star-fish yielded phosphate of lime, others none; hence the covering of that genus of animals seems to be intermediate between shell and crust.

With these observations of Mr Hatchett the analysis of Merat-Guillot corresponds. From lobster crust he obtained,

Carbonate of lime, . .	60
Phosphate of lime, .	14
Cartilage, . .	26
	100*

* Ann. de Chim. xxxiv. 71.

One hundred parts of cray fish crust contain

Carbonate of lime,	60
Phosphate of lime,	12
Cartilage,	28
	100*

John analyzed the shield or shell of the fresh water crab in 1811† and extracted from it the following constituents,

Cartilage,	33·3
Carbonate of lime, including a little common salt, iron, manganese, and colouring matter,	61·0
Phosphate of lime,	5·7
	100·0

Lobster's claws were subjected to analysis by M. Pagurus in 1823. He obtained

Animal matter,	17·18
Carbonate of lime,	68·36
Phosphate of lime,	14·06
	99·60‡

The shell of the lobster gave him

Animal matter,	28·6
Soda salts,	1·6
Carbonate of lime,	62·8
Phosphate of lime,	6·0
Phosphate of magnesia	1·0
	100·0

One hundred parts of hen's egg-shells contain

Carbonate of lime,	89·6
Phosphate of lime,	5·7
Animal matter,	4·7
	100.0§

* Merat-Guillot, Ann. de Chim. xxxiv. 71.
† Chemische Untersuchungen, ii. 49.
‡ Schweigger's Jour. xxxix. 440.
§ Vauquelin, Ann. de Chim. xxix. 6.

CHAPTER VII.

OF ZOOPHYTES.

Many of the substances called *zoophytes* have the hardness and appearance of shell or bone, and may therefore be included among them without impropriety. Others, indeed, are soft, and belong rather to the class of membrane or horn; but of these very few only have been examined. Indeed scarcely any chemical experiments have been published on these interesting subjects, if we except the dissertation by Hatchett, in the Philosophical Transactions for 1800, which has been so often quoted. From this dissertation, and from a few experiments of Merat-Guillot, we learn that the hard zoophytes are composed chiefly of three ingredients: 1. An animal substance of the nature of coagulated albumen, varying in consistency; sometimes being gelatinous and almost liquid, at others of the consistency of cartilage. 2. Carbonate of lime. 3. Phosphate of lime.

In some zoophytes the animal matter is very scanty, and phosphate of lime wanting altogether; in others the animal matter is abundant, and the earthy salt pure carbonate of lime; while in others the animal matter is abundant, and the hardening salt a mixture of carbonate of lime and phosphate of lime; and there is a fourth class almost destitute of earthy salts altogether. Thus, there are four classes of zoophytes; the first resemble porcelaneous shells, the second resembles mother-of-pearl shells, the third resembles crusts, and the fourth horn.

1. When the *Madrepora virginea* is immersed in diluted nitric acid it effervesces strongly, and is soon dissolved. A few gelatinous particles float in the solution, which is otherwise transparent and colourless. Ammonia precipitates nothing; but its carbonate throws down abundance of carbonate of lime. It is composed, then, of carbonate of lime and a little animal matter. The following zoophytes yield nearly the same results:

Madrepora muricata.
———— labyrinthica.
Millepora cerulea.
———— alcicornis.
Tubipora musica.

2. When the *Madrepora ramea* is plunged into weak nitric

acid, an effervescence is equally produced; but after all the soluble part is taken up, there remains a membrane which retains completely the original shape of the madrepore. The substance taken up is pure lime. Hence this madrepore is composed of carbonate of lime, and a membranaceous substance which, as in mother-of-pearl shells, retains the figure of the madrepore. The following zoophytes yield nearly the same results:

Madrepora fascicularis.
Millepora cellulosa.
——— fascialis.
——— truncata.
Iris hippuris.

The following substances, analyzed by Merat-Guillot, belong to this class from their composition, though it is difficult to say what are the species of zoophytes which were analyzed. By *red coral* he probably meant the *Gorgonia nobilis*, though that substance is known, from Hatchett's analysis, to contain also some phosphate.

	White Coral.	Red Coral.	Articulated Coralline.
Carbonate of lime,	50	53·5	49
Animal matter,	50	46·5	51
	100	100·0	100*

3. When the *Madrepora polymorpha* is steeped in weak nitric acid, its shape continues unchanged; there remaining a tough membranaceous substance of a white colour and opaque, filled with a transparent jelly. The acid solution yields a slight precipitate of phosphate of lime when treated with ammonia, and carbonate of ammonia throws down a copious precipitate of carbonate of lime. It is composed, therefore, of animal substance, partly in the state of jelly, partly in that of membrane, and hardened by carbonate of lime together with a little phosphate of lime.

Flustra foliacea, treated in the same manner, left a finely reticulated membrane, which possessed the properties of coagulated albumen. The solution contained a little phosphate of lime, and yielded abundance of carbonate of lime when treated with the alkaline carbonates. The *Corallina opuntia*, treated in the same

* Merat-Guillot, Ann. de Chim. xxxiv. 71.

manner, yielded the same constituents; with this difference, that no phosphate of lime could be detected in the fresh coralline, but the solution of burnt coralline yielded traces of it. The *Iris ochracea* exhibits the same phenomena, and is formed of the same constituents. When dissolved in weak nitric acid, its colouring matter falls in the state of a fine red powder, neither soluble in nitric nor muriatic acid, nor changed by them; whereas the tinging matter of the *Tubipora musica* is destroyed by these acids. The branches of this iris are divided by a series of knots. These knots are cartilaginous bodies connected together by a membranous coat. Within this coat there is a conical cavity filled with the earthy or coralline matter; so that, in the recent state, the branches of the iris are capable of considerable motion, the knots answering the purpose of joints.

When the *Gorgonia nobilis*, or red coral, is immersed in weak nitric acid, its colouring matter is destroyed, an effervescence takes place, and the calcareous part is dissolved. There remains an external tubulated membrane of a yellow colour, inclosing a transparent gelatinous substance. The solution yields only carbonate of lime: but when red coral is heated to redness, and then dissolved, the solution yields a little phosphate of lime also. Red coral is composed of two parts: an internal stem, composed of gelatinous matter and carbonate of lime; and an external covering or cortex, consisting of membrane hardened by the calcareous salts, and both coloured by some unknown substance.

The *Gorgonia ceratophyta* likewise consists of a stem and cortex. The stem is composed of cartilage, hardened chiefly by phosphate of lime; and containing little carbonate of lime; but the cortex consists of membrane, hardened almost entirely by carbonate of lime. The *Gorgonia flabellum* is almost exactly similar. The cortex of the *Gorgonia suberosa* yielded gelatine to boiling water; when steeped in acids, it left a soft yellowish membrane, and the acid had taken up a little phosphate and a large portion of carbonate of lime. The stem contained scarcely any earthy salt. When burnt, it left a little phosphate of lime. To water it yielded a little gelatin; but it consisted chiefly of a horny substance, analogous to coagulated albumen. The *Gorgonia setosa* and *pectinata* exhibited the same phenomena.

4. *Gorgonia antipkctes*, like the other species of gorgonia, has a horny stem, but it is destitute of a cortex. To boiling water

it gives out some gelatin. When steeped in nitric acid it becomes soft, and exhibits concentric coats of thin opaque brown membranes, of a ligneous aspect. It contains no earthy salt. With potash it forms an animal soap, and possesses nearly the properties of horn.

The stems of the *Gorgonia umbraculum* and *verrucosa* resemble that of the Gorgonia antiphates; but these are both provided with a cortex composed of membrane and carbonate of lime.

The *Antiphates ulex* and *myriophyla* resemble almost exactly the horny stem of the Gorgonia antiphates.

Mr Hatchett analyzed many species of sponges, but found them all similar in their composition. The *Spongia cancellata, oculata, infundibuliformis, palmata,* and *officinalis,* may be mentioned as specimens. They consist of gelatin, which they gradually give out to water, and a thin brittle membranous substance, which possesses the properties of coagulated albumen. Hence the effect of acids and alkalies on them.

The *Alcyonium ficus, asbestinum,* and *arboreum,* resemble very much the cortex of the Gorgonia suberosa in their composition. They yield a little gelatin to water. In nitric acid they soften, and appear membranous. The acid takes up the carbonate of lime, and likewise a little phosphate, at least when the substance has been previously heated to redness.

CHAPTER VIII.

OF BRAIN AND NERVES.

The *brain,* that wonderful part of the human body upon which the exercise of the different senses and of the understanding depends, is situated within the cranium, and is usually divided into the *cerebrum* and the *cerebellum,* or the *brain,* and the *little brain.* The cerebrum is situated farthest up, and is the part of the brain which comes into view when the parietal and frontal bones are removed. In an adult individual it is about eight times the size of the cerebellum.

The brain is enveloped in three membranes, which have received the names of the *dura mater, pia mater,* and *arachnoid mem-*

brane. The *dura mater*, which is most external of the three, is thick, firm, and resisting, and consists, in fact, of the two coats; the outermost one being fibrous, and the innermost serous. It lines the cranium or scull, to which it is attached, while, at the same time, it invests the brain, and sends in processes which are interposed between its different parts. The *pia mater*, which is in contact with the brain, is a thin lamella of cellular tissue, permeated by numerous minute capillary arteries. It invests the *medulla spinalis* as well as the brain, and dips into the sulci between the convolutions of the latter. The *arachnoid membrane* is smooth and transparent. One part of it invests the spinal cord and the brain, passing over its surface, without dipping into the convolutions. The other lines the *dura mater* and its several processes with which it is connected.

The brain occupies the principal part of the cranial cavity. Its superior surface is convex and arched; and is divided into two equal and similar hemispheres by the duplication of the *dura mater* called the *falx*. The surface of the brain is rendered unequal by several depressions and elevations marked upon it. The elevations are called *convolutions*, and are situated between the depressions. The brain itself consists of two substances; the outermost portion has a gray colour, and is called the *cortical* part, while the innermost portion, which is white, is called the *medullary* part. The cortical part forms a layer of variable thickness on the surface of the cerebrum and cerebellum. It is found also within the brain; sometimes it is covered by the medullary portion; sometimes it seems intimately mixed with it; or the two substances are disposed in alternate layers.

The first person who attempted to ascertain the structure of the brain by microscopic observations was Leuwenhoek. In the year 1674, he announced that the medullary portion of the brain of a cow was composed of very subtile globules.* Della Torré stated that the brain consisted of a pulpy matter swimming in a viscid and transparent fluid.† According to the microscopical observations of Ehrenberg,‡ the cortical substance of the brain consists of a fine net-work of vessels, in many places containing particles of blood. This net-work is connected with the vessels of the *pia mater*. Besides this fine net-work, the cortical portion

* Phil. Trans. xi. 106. † Poggendorf's Annalen, xxviii. 449.
‡ Ibid. xxviii. 451.

of the brain consists of a very fine granular soft mass, in which here and there larger grains are deposited in nests or layers. The larger grains are free; the very fine grains, whenever their softness, smallness, and transparency allow them to be seen, are united together in rows by very delicate threads. The white or medullary substance shows also many distinct fibres, continuations of the cortical fibres, and passing in the same direction towards the base of the brain. They are not simple cylindrical threads; but resemble strings of pearls, the pearls not being in contact, but kept at a little distance from each other. They are always straight, commonly parallel, sometimes crossing each other; in some rare cases they may be seen splitting into two, but not anastomosing. Near the bases of the brain we find between knotty bundles of fibres much thicker fibres always isolated. These last show distinctly an inner and outer limit of their walls, from which it is evident that they are hollow tubes. We may call them *varicose tubes* or *canals,* because they swell out in many places, resembling little blown bladders attached to each other by a narrow tube.

The interior of these varicose tubes is quite transparent, so that we might conceive them to be filled with vapour or with water. The milk-white colour which they have when viewed by the naked eye, is owing to the liquid contained in them, being of a milk-white colour, and somewhat muddy. This matter even when magnified 3000 times, does not exhibit any granular substance as the cause of this muddiness. The milk-white colour is wanting in the cortical substance of the brain. It consists of the points or beginnings of the varicose tubes, which exhibit their walls or boundaries, but want the bulky contents which exist in the medullary tubes. From this it is evident that the white colour is owing entirely to the contents of the tubes. When the tubes are torn, they contract; but nothing can be perceived coming out of them. The large brain tubes converge towards the place in the basis of the brain from which the nerves proceed, and pass over their origins.

The *nerves* of the senses—seeing, hearing, and smelling, together with the great sympathetic, consist of cylindrical parallel tubes about $\frac{1}{120}$th of a line in diameter, running close to each other, but not anastomosing. They are united in bundles, which again form larger bundles, called nervous *cords.* Each

bundle witn the whole cord is covered by a continuation of the *pia mater*. Very often different nervous bundles unite by *false* anastomoses, the tubes of one bundle passing into another, and running along with it; yet two tubes never unite together so as to become one, as happens with the blood-vessels. In the great sympathetic minute-jointed or varicose tubes may be distinctly seen mixed with larger cylinders.

The first attempt to analyze the brain was made by M. Thouret in 1790.* It was at that time that a vast number of dead bodies which had been burried in the *Saintes Innocens'* burial-ground in Paris were exhumed, and it was observed with some surprise, that in many of these bodies the brain, after an interval of a great many years, remained still unaltered, and free from putrefaction. M. Thouret made some experiments on the brain, in order to account for this long preservation, and concluded from them that the brain is a *soap*, composed of an oily matter similar (if not the very same) with spermaceti united to a fixed alkali.

In 1793 M. Fourcroy published a set of experiments on the brains of calves, sheep, and man. * He showed that the brain, besides the animal matter of which it chiefly consists, contains a small quantity of the phosphates of lime, ammonia, and soda; but no free fixed alkali, as Thouret had stated. He subjected the animal matter of brain to the action of heat, of water, of sulphuric acid, of dilute nitric acid, of muriatic acid, and of alcohol. The last reagent when boiled with brain dissolved a portion of it, which was deposited, as the alcohol cooled, in brilliant plates of a yellowish-white colour. This was the substance which Thouret considered as analogous to spermaceti; but which Fourcroy showed had no analogy whatever to that substance. He considered it as constituting a peculiar substance differing from every other; (though he did not distinguish it by any peculiar name,) but approaching nearer to albumen than to anything else. In 1812, Vauquelin published a set of experiments on the cerebral matter of man and some other animals.‡ He treated the brain successively with boiling alcohol as long as that liquid continued to dissolve anything; it deposited, on cooling, a white matter in plates, the same as had been previously observed by

* Jour. de Phys. xxxviii. 329. † Ann. de Chim. xvi. 282.
‡ Annals of Philosophy, i. 332, or Ann. de Chim. lxxxi. 37.

Fourcroy. Another fatty matter remained in solution, and was obtained by distilling off the greatest part of the alcohol, and drying the residue by heat. Vauquelin concluded from his experiments that the constituents of the brain were

Water,	80·00
White fatty matter,	4·53
Reddish fatty matter,	0·70
Albumen,	7·00
Osmazome,	1·12
Phosphorus,	1·50
Acids, salts, and sulphur,	5·15
	100·00

The salts were phosphates of potash, lime, and magnesia and a little common salt.

In 1816 a number of experiments on the brain of calves and oxen was published by John.* In 1830 Lassaigne gave a chemical analysis of the retina and the optic nerves.† The retina has been generally considered by anatomists as a mere expansion of the optic nerve, and this opinion has been confirmed by Lassaigne, who found the constituents of each the same, excepting that the retina contained much more water than the optic nerve. The constituents of the retina were,

Water,	92·90
Saponifiable fat and cerebrin,	0·85
Albumen,	6·25
	100·00

While the optic nerve gave,

Water,	70·36
Cerebrin,	4·40
Osmazome and common salt,	0·42
Gelatin,	2.75
Albumen,	22·07
	100·00

In 1834, M. Couerbe published an interesting set of experiments on the brain.‡ He employed both alcohol and ether as

* Chemische Untersuchungen, iv. 160.

† Ann. de Chim. et de Phys. xlv. 215.

‡ Ibid. lvi. 160.

solvents, and discovered, besides Vauquelin's white substance, to which the name of *cerebrote* was given, four other constituents, namely, *cholesterin*, *cephalote*, *stearoconote*, *and eleancepholote.*

An elaborate set of experiments on the analysis of the brain was published by Fremy in 1841.* He confirmed the existence of cerebrote and cholesterin, discovered by Vauquelin and Couerbe. But showed that cerebrote, when pure, possesses acid properties, and on that account distinguished it by the name of *cerebric acid.* He found also in brain an acid to which he gave the name of *oleophosphoric;* which he considers as a compound of olein and phosphoric acid. He extracted also oleic and margaric acid from brain, and agrees with Vauquelin in admitting the presence of a considerable quantity of albuminous matter. The cephalote, stearoconote, and eleancepholote of Couerbe, M. Fremy could not obtain. He considers them as mixtures of the different oily acids contained in the brain, and differing in their properties, and in the proportion of their constituents according to circumstances.

All that has hitherto been done towards an analysis of the brain is to determine the nature of the substances which are taken up from it by ether and alcohol. After the action of these substances has been exhausted, the residual matter is almost as bulky as ever. And this residual matter has not yet been subjected to examination. It consists, doubtless, of the minute varicose tubes described by Ehrenberg. The nature of this matter has not hitherto been determined; but it contains a very great proportion of water. Couerbe's analysis being the completest, it will be proper to state the results which he obtained. The brain was in the first place stripped off the coats which cover it, and washed in cold water in order to deprive it as completely as possible of blood.

It was then reduced to pulp in a mortar and macerated in cold ether. Four successive macerations were requisite to deprive the brain of every thing which the ether was capable of dissolving. Indeed the first maceration did little more than deprive it of water. The ether being distilled off, and the residue dried in a capsule to drive off the residue of ether, what remained was a white fatty substance, partly in streaks and partly in grains. When the brain thus treated was from a sound individual, almost the whole of this matter was *cerebrote.* When the brain was

* Jour. de Pharm. xxvii. 453.

that of an insane person, the cerebrote was combined with some other substances. To separate them digest the fatty residue in a little ether. Sometimes the cerebrote remains undissolved, and may be obtained by passing the etherial solution through a filter. When the ether dissolves the whole, as sometimes happens, we must evaporate to drive off the ether, and then subject the white fatty matter to the action of boiling alcohol. The alcohol dissolves three different fatty bodies, one of which is cerebrote, and leaves undissolved a sold brown substance resembling wax.

When this brown substance is digested in ether, the greater part of it is dissolved, but a brown powder remains, which Couerbe has distinguished by the name of *stearoconote*.

The ether being evaporated, leaves a faun-coloured substance, which cannot be sufficiently dried to assume the form of a powder. To this brown matter Couerbe has given the name of *cephalote*. It was first noticed by Kuhn; but it is to Couerbe we are indebted for the knowledge of its properties.

The alcoholic solution is filtered through animal charcoal, and then left to itself. White fatty crystals are deposited, and an additional quantity of them is obtained by concentrating the liquid. These crystals being treated with ether, cerebrote is left in a state of purity, while the ether dissolves a quantity of *cholesterin*, which may be obtained in crystals by evaporating the etherial liquid.

When the alcoholic liquid from which the crystals had been deposited has been weakened by repeated concentrations, a red oily matter begins to appear. To obtain this oil in a separate state the liquid must be put into a linen cloth and squeezed. The alcohol with the oil passes through the cloth, while the crystals, consisting of cholesterin and cerebrote, remain. Add to the muddy alcoholic liquid a little ether, which will dissolve the oil, and render the liquid transparent. Set the solution aside. The oil gradually subsides while the crystalline matter remains dissolved in the ether. When enough has subsided it may be purified by filtration. To this oil Couerbe has given the name of *eleancephalote*. *

* I think it right to state that I attempted to extract these various bodies described by Couerbe from the human brain; but, with the exception of cerebrote and cholesterin, I was unsuccessful.

The portion of brain which had been digested in ether was next treated with boiling alcohol repeatedly, as long as any white matter was deposited, when the alcohol cooled. This white matter was *cerebrote;* the substance which had been already obtained by Vauquelin by a similar process, and which he had distinguished by the name of cerebral matter.

The brain deprived of these fatty matters has not materially changed its appearance or its bulk. Vauquelin has shown that this *neurilema* contains albumen and coagulated globules of a membranous substance, soluble in potash. This substance, when dried, assumes a gray colour, a semitransparence, and a fracture similar to that of gum arabic. When put into water it becomes opaque, swells up and softens, and water dissolves a very small portion of it. Thus softened it readily dissolves in caustic potash by the assistance of heat, and during the solution no ammonia is disengaged. The potash solution is slightly brown, and has a weak smell. The acids throw it down in white flocks, and disengage a very fetid odour. When acetate of lead is dropt into the solution, a dark brown precipitate falls, showing the presence of sulphur. When cautiously distilled, it furnishes carbonate of ammonia in crystals, and a red oil similar to that which albumen yields when treated in the same way.

According to Vauquelin, the *medulla oblongata* and *spinalis* are of the same nature with the brain, but contain much more fatty matter, and less albumen, osmazome, and water. Hence, the reason why the spinal marrow has greater consistence than the brain. The portion insoluble in alcohol is albumen.

The nerves are likewise of the same nature as the brain, but they contain much less fatty matter and much more albumen. They contain besides common fat, which separates from them when treated with boiling alcohol. When the nerves are deprived as much as possible of their fatty matter by alcohol, they become transparent. When digested in that state in boiling water, they do not dissolve but become white, opaque, and swell up obviously in consequence of absorbing moisture. The residue of nerve which has been treated with alcohol and water dissolves almost completely in caustic potash. No ammonia is evolved during the solution. The potash solution is precipitated in purple flocks by acids.*

* Annals of Philosophy, i. 345.

CHAPTER IX.

OF MUSCLES.

The *muscles* of man, and indeed of all the mammalia, birds, and fishes, constitute by far the greatest part of the body. They are the organs of motion, and constitute what in common language is called *flesh*. In man, the muscles are divisible into two kinds, 1. Those which are attached to the bones, and 2. Those of the viscera. The former, a few excepted, have a red colour in warm-blooded animals, but are white in the greater number of fishes. The latter are annular, as in the intestinal canal and urinary bladder. They are usually pale, if we except the heart, the muscles of which have the same colour as those attached to the bones.

The muscles consist of a congeries of fibres, usually parallel to each other. Each of these fibres, when viewed under the microscope, is composed of a number of smaller fibres, and the smallest fibres of all, or what may be called the element of the muscle, was believed by Leuwenhoeck to be a congeries of spherical molecules, applied to each other so as to constitute a thread,* and this opinion has been confirmed by subsequent observers. These globules consist of *fibrin*. Every muscular fibre is enclosed in a very delicate sheath of cellular substance. A number of these fibres associated together is covered and held together by another delicate sheath of the same cellular substance. Several of these are in their turn enveloped in a new common sheath of the same substance. Thus, the whole muscle is composed of numerous muscular fibres collected together in bundles, and held together by connecting cellular substance. Hence it is easier to tear these fibres from each other than to break them in a direction perpendicular to their length.

The structure of muscle has been investigated with much care by Mr Skey,† who has confirmed the statements of Messrs Hodgkin and Lister, that the ultimate filaments of muscle are not composed of globules, but are hollow tubes, the size of which does not exceed $\frac{1}{10000}$th of an inch. They are collected into

* Phil. Trans. 1677, Vol. xii. p. 899. † Phil. Trans. 1837, p. 371.

fibres about $\frac{1}{400}$th of an inch in diameter, and surrounded by circular striæ varying in thickness and in number. Each fibre is divided into bands or fibrillæ composed of many ultimate filaments. Each fibrilla is divided into filaments, of which every fibre of $\frac{1}{400}$th of an inch diameter contains about 100. The diameter of the filaments is about one-third the size of the globules of the blood.

Muscles, while they retain their vitality, contract when stimulated either by the prick of any sharp instrument, or by the application of any acrid or stimulating substance. When they lose this property they are considered as dead. Sir Anthony Carlisle has shown that a muscle is stronger while it retains its irritability, than when it has lost that property. He laid bare the muscles of the two hind thighs of a frog, and removed the femoral bone. He then attached weights to each set of muscles till it was ruptured. The experiment was made upon the muscles of one leg while they retained their irritability, and upon the muscles of the other leg, after the irritability was gone. The muscles retaining their irritability were ruptured by a weight of six pounds avoirdupois; those that had lost it by a weight of five pounds.*

Through the muscular fibres run a great number of blood-vessels and nerves. These may be removed to a certain extent, but not completely. Especially the nerves, which are very numerous, and which become at last transparent and invisible without any sensible termination ; the cellular substance also which surrounds the muscular fibres, and divides them into bundles, is a substance of quite a different nature from the muscular fibre itself, and would require to be removed before the chemical nature of that fibre could be accurately determined. The red colour of the muscle is doubtless owing to the existence in it, of a vast number of capillary vessels filled with red blood.

The first attempt at a chemical examination of the muscles of animals was by M. Claude-Joseph Geoffroy, Junior, in 1730.† He examined the flesh of oxen, calves, sheep, fowls, pigeons, pheasants, partridges, in order to determine how much of each was soluble in water by boiling, and how much each lost when dried over the steam-bath. The subject was farther continued

* Phil. Trans. 1805, p. 3.

† Memoires de l'Academie des Sciences, 1730, p. 217.

by him in 1832.* But chemical analyses were made at that early period with so little attention to exactness, that it would not be safe to trust to his results.

Towards the end of the eighteenth century, Thouvenel repeated some of the experiments of Geoffroy with more precision, and found that when flesh was boiled in water, not only gelatin was dissolved, but likewise a particular extractive matter which fixed his attention. About the year 1802, when Fourcroy published his General System of Chemical Knowledge, he gave an account of a set of experiments which he had made to analyze the muscles of animals.† Thenard‡ soon after examined the matter dissolved from the muscle by alcohol, and gave it the name of *osmazome*. Mr Hatchett, in his Experiments on Zoophytes, published in the Philosophical Transactions for 1800, (p. 327), has given an account of numerous experiments on the component parts of membranes, and, among other things which he examined, was the muscular fibre of beef. He freed it as much as possible from all foreign matter, and then examined it by means of different reagents. Berzelius, in his Animal Chemistry, the second volume of which, containing his account of muscles, was printed in 1808, gives an account of an analysis which he had made of muscle. Besides the substances previously detected by Fourcroy and Hatchett, he found also lactate of soda.§ He says in his system that he discovered at the same time lactates of potash and lime;‖ but I do not find any mention of these salts in his Animal Chemistry. In 1821, Braconnot published an analysis of the heart of an ox, in order to compare it with the excrements of a nightingale which had been fed on that heart.¶ These, so far as I know, are the only chemists who have examined the chemical characters and constitution of *muscles*.

Mr Hatchett took a piece of lean beef, cut it into thin small pieces, and macerated it for fifteen days in cold water, subjecting it each day to pressure, and changing the water. The shreds of muscles, which amounted to about three pounds, were then boiled with about six quarts of water during five hours, and

* Memoires de l'Academie des Sciences, 1732, p. 17.

† Fourcroy's System, ix. 334. ‡ Traité de Chimie, iv. 643.

§ Djurkemien, ii. 170. ‖ Traité de Chimie, vii. 493.

¶ Ann. de Chim. et de Phys. xvii. 388.

the water being changed each time, the same boiling process was repeated every day for three weeks; at the end of which time the water afforded only slight signs of gelatin when infusion of oak bark or chloride of tin was added. After this the fibrous part was well pressed, and was dried by the heat of the water-bath. Muscle thus treated is as pure as it can be made by any known process. The cold water removes the blood and lymph, and the hot water dissolves the cellular substance, and converts it into gelatin. The minute blood-vessels and nerves, which cannot be separated mechanically, still remain.

Muscle thus treated contracts in its dimensions, has a dirty-yellow colour, and is brittle, and easily reduced to powder. Though steeped in water, it does not recover its former flexibility. 100 parts of muscle when dried are reduced to 17 parts, so that the solid portion does not much exceed a sixth part of the whole.

Muscle not boiled, when digested in acetic acid, is converted into a jelly, which dissolves in water; but the solution is muddy, and very difficult to filter. When the solution is left long at rest, a quantity of fatty matter collects on the surface, and a grey matter is deposited, consisting (probably) of minute blood-vessels which have not dissolved in the acid.

Dilute caustic potash dissolves it when assisted by a gentle heat. The solution is muddy, and can scarcely be filtered. What remains undissolved is probably cellular matter, which dissolves also when the temperature of the solvent in raised. When muriatic acid is poured into the alkaline solution, a compound of the acid and fibrin precipitates, which may be washed in dilute muriatic acid; but dissolves in water, becoming in the first place gelatinous and transparent.

When washed muscle is exposed to pressure there exudes a red liquid, which does not coagulate like blood, and which has the property of strongly reddening litmus-paper. To obtain the whole of this liquid we must digest the muscle in water. This liquid was subjected to a chemical examination by Berzelius. He obtained,

1. *Albumen.* When the liquid is heated it becomes muddy at 122°, and a copious precipitate falls at 126°, in colourless flocks, which are easily separated by the filter. This precipitate becomes white when washed. The liquid from which the precipi-

tate fell has a deep red-colour like that of venous blood. At 134°, the greatest part of the matter which it holds in solution coagulates, and if we keep it for half an hour at that temperature we obtain a colourless cake. At 144° another coagulum falls, having a reddish gray colour ; but the colour of the liquid from which it fell still continues unaltered. At a higher temperature the colouring matter coagulates; but its quantity is very small compared to the preceding deposits. These different precipitates indicate albumen, probably derived partly from the blood circulating in the muscle, and partly from the nervous filament which it contains. The coagulating temperature is lower than that of albumen in the serum of the blood. But that may depend upon the acid present, or upon its state of dilution or concentration.

The colourless coagulated albumen reddens litmus-paper, and this property cannot be removed by washing. When dried its colour becomes deeper, and at last almost quite black. Boiling alcohol extracts from it a little fatty and a little animal matter, which Berzelius considers as a combination of albumen with an acid. When long digested with water over calcareous spar in powder a little lactate of lime is formed. The liquid assumes a yellow colour, but holds in solution only a minute quantity of animal matter. This shows that the precipitate from the liquid of muscle by heat is not casein. It dissolves readily in carbonate of potash, and the solution has all the characters of a solution of albumen.

2. *Lactic acid.*—If we filter the liquor from which the albumen has been separated by heat, and evaporate it to dryness, it leaves a yellowish brown extract, more than the half of which is dissolved by alcohol of the specific gravity 0·833. When the alcoholic solution is evaporated to dryness there remains an extractiform mass, mixed with crystals of common salt, which has a strongly acid reaction; but leaves when burnt some alkaline carbonate. Hence it follows that the matter contained a combustible acid, partly free and partly combined with potash. If we mix the alcoholic solution with a solution of tartaric acid in alcohol, there separate bitartrates of potash and soda and tartrate of lime, and there remains in solution in the liquid, besides tartaric acid and muriatic acid, the combustible acid. If we digest the liquor with carbonate of lead in fine powder till a portion of the lead remains in solution the tartrate and chloride of lead precipitate. If

we evaporate the alcohol and dissolve the residue in water, and pass through it a current of sulphuretted hydrogen gas to precipitate the lead, and then boil the aqueous liquid with animal charcoal, and evaporate, we obtain a colourless very acid syrup, possessing all the characters of lactic acid.

3. *Salts.*—These are of two kinds; namely, those which are soluble in alcohol, and those which are only soluble in water.

The salts soluble in alcohol are the lactates of potash, soda, lime, and magnesia, together with traces of lactate of ammonia, likewise chloride of potassium and chloride of sodium. If we evaporate the alcoholic solution to dryness, and digest the residue in absolute alcohol, the lactates will be dissolved, while the chlorides will remain unacted on.

When the solution in absolute alcohol is treated with an alcoholic solution of tartaric acid, the precipitate, when incinerated, leaves a good deal of carbonate of potash and a little carbonate of soda. These carbonates being dissolved, a white powder remains, which dissolves with effervescence in muriatic acid, leaving undissolved a trace of phosphate of lime. If we saturate the solution with ammonia, oxalic acid precipitates the lime. The lime being removed, phosphate of ammonia, mixed with a little ammonia, throws down a small quantity of ammonia-phosphate of magnesia.

The salts insoluble in alcohol are the phosphates of soda and of lime.

4. *Animal extractive matter.*—This is partly soluble in alcohol of 0·833, and partly only in water.

(1.) The alcoholic extractive matter is what Thenard called *osmazome.* It is a mixture of various substances; among others of lactic acids and lactates. When alcohol of 0·833 is digested upon extract of flesh, it divides it into two nearly equal portions; the alcohol acquires a yellow colour, and leaves a brown viscid matter, which is the portion soluble in water.

When the alcohol is distilled off, and the residue dried over the steam-bath, there remains a transparent yellow matter mixed with crystalline grains. When this matter is digested in absolute alcohol, the greater portion of it is dissolved, and the solution has a light colour and is transparent. If we distil off the absolute alcohol, a syrup remains, which cannot be dried over the steam-bath but remains semiliquid. It has an acrid and saline taste. Its smell is at first similar to that of burnt bread, but

when kept, it exhales an urinous odour, especially when ammonia is added to it. When heated in an open dish it gives out a very strong urinous smell; it is then charred, and gives out a smell exactly similar to that of burnt tartar, and finally swells up, as happens to a vegetable acid united to an alkaline base. It dissolves in water, and the solution has a yellow colour. Infusion of nutgalls and corrosive sublimate throw down a very scanty precipitate; and this is the case also with acetate of lead and nitrate of silver. Diacetate of lead throws down a very copious precipitate; oxalic acid throws down oxalate of lime; lime-water throws down nothing. But if we mix the extract with a good deal of hydrate of lime, and boil for a long time, a disagreeable ammoniacal smell is disengaged, the hydrate becomes yellow, and a great proportion of the extract is decomposed. If it be now treated with animal charcoal, little remains but lactic acid and salts, which may then be separated. Nitric acid occasions the formation of no nitrate of urea, but after some weeks crystals of saltpetre make their appearance, from the decomposition of lactate of potash.

The extractive matter soluble in absolute alcohol contains at least two substances, which were separated from each other by Berzelius in the following manner:

(1.) Corrosive sublimate threw down a yellow precipitate, which was mixed with water, and a current of sulphuretted hydrogen passed through the mixture. A yellow solution remained, which had an acid reaction. When saturated with carbonate of lead and evaporated, it left a deep yellow matter, from which neither absolute alcohol nor alcohol of 0·833 is capable of dissolving the extractive which remains combined with the chloride of lead. But it readily dissolves in water, and the solution is precipitated by corrosive sublimate, but not by acetate of lead or protochloride of tin, and very little by diacetate of lead. Nitrate of silver throws down the extractive matter combined with chloride of silver. This portion of extractive matter possesses the following properties: its colour while in solution is light-yellow; it has no taste, and has a great tendency to combine with salts, on the nature of which depends its solubility or insolubility in alcohol. Its compound with corrosive sublimate is orange. It is slightly soluble in water, but not in water containing an excess of corrosive sublimate. It is this substance

which tannin precipitates from the extract obtained by anhydrous alcohol. It constitutes but a small portion of that extract.

(2.) When diacetate of lead is poured into the liquid, which has been precipitated by corrosive sublimate, and which contains an excess of this last substance, a small quantity of a yellowish precipitate falls quite similar to what urine furnishes in a similar case. This precipitate consists of dichloride of lead with a little dilactate of lead, both united to an extractive matter. If we wash this precipitate and decompose it by sulphuretted hydrogen, we obtain a yellowish liquid which has an acid reaction. If we saturate this liquid with carbonate of lead, evaporate to dryness, digest the residual matter in alcohol, drive off the alcohol, and decompose the residue by sulphuretted hydrogen and evaporate, we obtain a yellow transparent matter, which contains a little free lactic acid, exhales a weak urinous smell when evaporated, and is not precipitated by any of the reactives above stated. It combines with chloride of barium, and with other salts, precisely as the corresponding matter from urine does.

The portion of the alcoholic extract insoluble in absolute alcohol is a viscid mass having a deep yellow colour, and generally opaque. It is no longer completely soluble in alcohol of 0·833. That alcohol dissolves a portion of it, and assumes a yellow colour. When evaporated, it leaves an extract, mixed with a combustible salt. It has no determinate taste. When heated cautiously till it begins to become brown, it gives out the smell of roast-meat. If we now dissolve it in water, and treat it with animal charcoal, most of the extract is separated from the salt, which, after evaporation, remains in the state of a white mass, consisting of soda and potash united to a combustible acid, but without any salt of lime. The extractive matter when in solution is very slightly precipitated by infusion of nutgalls and corrosive sublimate, and not at all by acetate of lead and protochloride of tin. This extractive is the same as that which urine gives under the same circumstances.

The portion which the alcohol of 0·833 leaves undissolved has a deep-brown colour, and is mixed with crystals of common salt. It dissolves in water, and the solution has a brown colour. This extract consists of two substances, one of which is precipitated by corrosive sublimate, and the other by protochloride of tin.

The precipitate by corrosive sublimate is deep-brown, and the

liquid over it is yellow. When decomposed by sulphuretted hydrogen, the residual liquid reacts as an acid. When concentrated to a certain point, the extractive which it contains may be precipitated by absolute alcohol, while the uncombined acid remains in solution. It is a brown magma, having a slightly bitter taste. It is soluble in water, and the solution has a brown colour. This aqueous solution is copiously precipitated by infusion of nut-galls and corrosive sublimate; but not by acetate of lead, protochloride of tin, or nitrate of silver. Diacetate of lead precipitates it abundantly. We obtain also a complete precipitate when, after having added protochloride of tin, we pour in a quantity of caustic ammonia.

When protochloride of tin is added to the yellow liquor which has been already precipitated by corrosive sublimate, a new precipitate falls, which is colourless, and from which sulphuretted hydrogen gas separates an almost colourless extractive, which is tasteless, and exhales an animal odour when burnt. Its solution is neither precipitated by acetate of lead nor infusion of nut-galls. The quantity of it is inconsiderable.

(2.) *Extractive Matter soluble in Water but not in Alcohol.*—Alcohol of 0·833 leaves a brown and opaque matter, having an agreeable taste of meat or *beef-tea*. It has an acid reaction, and contains lactic acid, which may be extracted in the following way: Dissolve the extractive matter in water, saturate it with carbonate of ammonia added in slight excess. Evaporate to the consistence of a syrup, and mix the residue with alcohol of 0·833. The lactate of ammonia, together with two extractive substances, will be dissolved.

If we dissolve in water what remains after the evaporation of the alcohol, and add infusion of nut-galls to the solution, a precipitate falls, which, though not quite insoluble in water, is yet almost wholly separated by an excess of tannin. After having collected this precipitate on a filter, and subjected it to pressure, it is soluble in boiling water, and the tannin may be separated from it by acetate of lead. The precipitate being separated, and the excess of lead thrown down by sulphuretted hydrogen, the liquid, when evaporated, leaves a yellow extractive matter, having the smell and taste of toasted bread, and soluble in water, to which it communicates a pale yellow colour. Its solution in water gives a copious white precipitate with corrosive sublimate;

a yellow precipitate with diacetate of lead and nitrate of silver. Acetate of lead and protochloride of tin occasion no precipitates.

If we deprive the liquid which has been precipitated, by the infusion of nut-galls, of its excess of tannin, by adding acetate of lead, drop by drop, as long as a precipitate falls, and then evaporate the filtered liquor over the steam-bath, an acid extractiform matter remains, which contains lactate of ammonia. When heated it gives out the smell of roast-meat. It is a mixture of lactate of ammonia, and of a quantity of extract identical with the portion left, when the matter dissolved by alcohol of 0·833 was digested in absolute alcohol.

The aqueous extract remaining after the preceding treatment with carbonates of ammonia and alcohol of 0·833, contains at least four different extractive substances. If we dissolve the mass in water, and then add caustic ammonia, and afterwards acetate of barytes, a precipitate of subphosphate of barytes falls, coloured brown by organic matter. A similar calcareous phosphate is precipitated by lime-water. If we wash the precipitate, and digest it in a stoppered phial with weak caustic ammonia, a portion of the organic matter is extracted, and a brownish yellow solution is formed, which, being filtered and evaporated to dryness, leaves a brownish yellow matter, having the characteristic taste of the aqueous extract. The barytic phosphate, however, still retains a portion of organic matter in combination.

The liquor from which this phosphate was precipitated, if it contain a great excess of alkali, must be neutralized by acetic acid. It is then to be completely precipitated by acetate of lead; saturating the acetic acid, as it becomes free, with ammonia. The precipitate obtained is light and has a yellow colour. It is to be collected on a filter, washed, mixed with water, and decomposed by sulphuretted hydrogen. The liquor thus treated must be heated to allow the sulphuret of lead to precipitate. The filtered liquor is brown, and this colour cannot be removed by animal charcoal. It has an acid reaction, and contains a little lactic and muriatic acids. We get rid of them by saturating them with ammonia, evaporating to the consistence of a syrup, and treating the matter with alcohol of 0·833. The ammoniacal salts are dissolved and the extractive matter remains.

It is a brown matter, which becomes hard when dried, and is not altered by exposure to the air. It has a strong and agree-

able taste of beef-tea, exactly similar to that of the substance into which fibrin is converted by boiling. It dissolves in all proportions in water, and is precipitated by alcohol. Yet it communicates a yellow colour to alcohol of 0·833, which of course dissolves a certain portion of it. Acetate of lead, protochloride of tin, and nitrate of silver throw down brownish yellow precipitates from its aqueous solution. It is not precipitated by corrosive sublimate, and only very slightly by infusion of nutgalls.

It is to this substance that boiled and roasted-meat owe their flavour. Muscular fibre and cellular substance of themselves are quite insipid, and the other extractive substances have but a very slight taste. Berzelius proposes to distinguish this extractive matter by the name of *zomidin.** Its characters are still very imperfectly investigated, and it is not probable that it has been obtained in a state of purity. Indeed, as most animal substances refuse to crystallize, we have no criterion by which we can judge of their purity or impurity.

The liquor precipitated by acetate of lead gives with diacetate of lead a new precipitate, which is almost colourless. If we decompose this precipitate by sulphuretted hydrogen, we obtain a liquid nearly colourless, which, when evaporated, leaves a transparent matter, similar in appearance to gum. When left to dry in the open air it is easily detached from the glass vessel on which it was placed. When burnt it gives out an acid smell. Its taste is similar to that of gum. It softens in water before dissolving, and it dissolves in that liquid very readily. This solution is not precipitated by acetate of lead, corrosive sublimate, nor nitrate of silver. But diacetate of lead throws down a mucous, colourless precipitate. Infusion of nut-gall renders it opal.

The liquid, which is no longer precipitated by the diacetate of lead, is colourless, provided it be deprived of all lead and filtered. When evaporated over the water-bath it becomes slightly yellow, and leaves a yellow mass, mixed with a great quantity of acetates. If we digest it in absolute alcohol to get rid of the acetates, a yellow matter remains having the following properties: It is yellowish-brown, has very little taste, and gives out animal odour when burnt. It dissolves easily in water, to which it communicates a yellow colour, leaving a small quan-

* From *ζωμιδιον, broth.*

tity of a yellow powder, similar to that of *apothem*. Its solution is not precipitated by corrosive sublimate, protochloride of tin, nor acetate of lead. But with diacetate of lead it gives a copious precipitate, which redissolves when acetate of lead is added. Nitrate of silver throws down a yellowish grey precipitate, and infusion of nut-galls renders it opal.

The solution in absolute alcohol is yellow, and contains a matter, which, being freed from alcohol and dissolved in water, is precipitable by infusion of nut-galls. If we dissolve this precipitate in boiling water, precipitate the tannin by acetate of lead, throw down the excess of lead by sulphuretted hydrogen, and filter and evaporate the liquid, we obtain a transparent substance having very little taste. Its aqueous solution is yellow, and exhibits with reagents nearly the same characters as the preceding substances.

Such is an abstract of Berzelius's experiments on the expressed juice of muscle. If we attend to the various vessels which exist in muscle, arteries, veins, and lymphatics, it must be obvious that a portion of these different substances must be derived from the liquids contained in these vessels. But the liquids contained in arteries, veins, and lymphatics are alkaline, while the liquid from the muscle contains an excess of lactic acid, and much more phosphate of lime than exists in blood or lymph. It is not in our power, in the present state of our knowledge, to explain the origin of these matters, nor of the numerous extractive matters which have been described. It is not unlikely that some of the substances described by Berzelius may have been produced by the various processes to which the liquor of muscle was subjected. Much light would be thrown on the subject by the ultimate analysis of the different extractive substances, especially of that one which has the taste and smell of roasted-meat, provided it could be obtained in a state of sufficient purity. Perhaps the precipitate which it forms with oxide of lead or oxide of silver might enable a good experimenter to determine its atomic weight and its ultimate constitution.

I am not aware that any muscles have been subjected to analysis except those of the ox. Hatchett and Berzelius made their experiments on the lean of beef, while Braconnot analyzed the heart of an ox. The following table exhibits the result of the analyses of Berzelius and Braconnot:

	Berzelius.
Muscular fibre, vessels, and nerves, 15·8 } Cellular substance soluble by carbon, 1·9 }	17·70
Soluble albumen and colouring matter,	2·20
Alcoholic extract with salts,	1·80
Aqueous extract with salts,	1·05
Phosphate of lime containing albumen,	0·08
Water,	77·17
	100·00 *

	Braconnot.
Fibrin, vessels, nerves, and cellular substances,	18·196
Albumen with colouring matter and phosphate of lime and magnesia,	2·733
Alcoholic extract,	1·566
Lactate of potash,	0·186
Phosphate of potash,	0·153
Common salt,	0·126
Water,	77·036
	100·000†

It is universally known that when flesh is left exposed to the air, it runs into putrefaction very rapidly, giving out an excessively disagreeable smell, and becoming soft and pulpy. But in an air-tight vessel freed from oxygen gas, it may be kept for years without any sensible alteration. In this way, it is often exported from this country to India; and I have eat beef perfectly fresh and good, after it had made a voyage to India and back again.

The action of reagents on muscle is the same as on fibrin. When very dilute acids are poured on flesh, a certain portion is absorbed, the flesh becomes harder, and much less liable to putrefaction. When the acids are stronger, the flesh swells out, and is converted into a jelly, which is soluble in water. Dilute caustic alkalies dissolve flesh slowly; but when they are concentrated, the solution is rapid. During the solution ammonia is evolved, and a little alkaline sulphuret formed. Salts having an alkaline base preserve flesh from putrefying. For this purpose

* Djurkemien, ii. 178. † Ann. de Chim. et de Phys. xxvii. 390.

common salt is usually employed. Several of the metalline salts combine with flesh precisely as they do with fibrin. This is the case with the salts of iron and mercury. It has long been known that a very small quantity of corrosive sublimate preserves anatomical preparations from putrefaction.

Muscles, it is well-known, are the organs by means of which all the different motions of the living body are performed. When a muscle acts the muscular fibres are shortened, while the belly of the muscle swells out, and the whole muscle occupies a greater bulk than before. Sir Anthony Carlisle introduced a man's arm within a glass cylinder. It was duly closed at the end which embraced the head of the humerus. The vessel being inverted, water at 97° was poured in so as to fill it. A ground brass plate closed the lower aperture, and a barometer tube communicated with the water at the bottom of the cylinder. This apparatus, including the arm, was again inverted, so that the barometer tube became a gage, and no air was suffered to remain in the apparatus. On the slightest action with the muscles of the hand or forearm, the water ascended rapidly in the gage, making librations of six and eight inches length in the barometer tube, on each contraction and relaxation of the muscles.*

When muscles are strongly contracted their sensibility to pain is nearly destroyed. This means is employed by jugglers for the purpose of suffering pins to be thrust into the calf of the leg and other muscular parts with impunity.† When fish are subjected to the process called *crimping*, the specific gravity of the muscles is increased. Crimping consists in cutting the muscles across at various distances before their vitality is destroyed. The sea-fish destined for crimping are usually struck on the head when caught, which, it is said, protracts the term of this capability; and the muscles which retain this property longest are those of the head. Many transverse sections of the muscles being made, and the fish immersed in cold water, the *contractions* called crimping take place in about five minutes; but if the mass be large, it often requires thirty minutes to complete the process. Sir Anthony Carlisle took two flounders, each weighing 1926 grains, the one being in a state for crimping, the other dead and rigid. They were both immersed in water of 48° tempera-

* Phil. Trans. 1805, p. 22. † Ibid. p. 27.

ture after being equally scored with a knife. The specific gravity of the crimped fish was 1·105, that of the dead fish, after an equal immersion in water, 1·090.

A piece of cod-fish, weighing twelve pounds, gained in weight by crimping two ounces avoirdupois, or rather more than one per cent.; and another less vivacious piece of fifteen pounds gained one ounce and a-half. The hinder limb of a frog having the skin stripped off, and weighing 77·1 grains, was immersed in water of 54°, and suffered to remain nineteen hours. It became rigid, and weighed 100·25 grains. So that the increase of weight amounted to 30 per cent., while at the same time the specific gravity had increased, as in the case of the crimped fish. 630 grains of the subscapularis muscle of a calf, which had been killed two days from the 10th of January, were immersed in hard-water at 45°. In ninety minutes the muscle was contracted, and weighed 770 grains. So that the increase of weight was rather more than 22 per cent.; while, at the same time, the specific gravity of the muscle had increased.*

Many attempts have been made to give a theory of muscular motion; but hitherto little satisfactory information on this intricate subject has been suggested. One of the latest and most ingenious theories on the subject is that of Prevost and Dumas. According to them, the nervous filaments enter the muscles at right angles, and, after having traversed the muscular fibres turn back and cross the same fibres in a direction parallel to their original one. A current of electricity passes through these nerves. It moves in one direction in the first portion, and in the opposite direction in the recurrent nerves. Hence the currents attract each other, the muscular fibres are shortened, and muscular motion produced. Before examining this theory, it would be necessary to establish by accurate anatomical dissections that the direction of the nerves is as these philosophers allege.

* Carlisle, Phil. Trans. 1805, p. 23.

CHAPTER X.

OF TENDONS.

TENDONS are strong pearl-coloured bodies, which terminate the muscles and attach them to the bones. They are known in common language by the name of *sinews*. They are of very various forms, according to their situation. Some are narrow and cord-like, as those which stretch across the wrist and ankle to reach the fingers and toes. Others are compressed and strap-shaped in the middle, and expanded at one or both extremities. The *tendo Achillis* is convex on its cutaneous surface and flat on the other, its fibres spreading out considerably where they run into those of the muscle. The tendon of the plantaris is very narrow and thin, but may be easily spread out to ten times its natural breadth.

Tendons are composed of fibres. They are very strong, and are so firmly united to the muscle to which they belong, that, when rupture takes place in consequence of any sudden and violent action, the tendon itself gives way, and not its junction with the muscle. Tendons are smooth, and are covered externally with a kind of loose sheath of cellular substance, which facilitates their motion on other bodies.

When a tendon has been softened in water, it may be spread on the finger like a membrane, and has a silvery lustre. This character enables us easily to distinguish the smallest tendons from vessels and nerves.

The fibres are longitudinal, and differ much in their appearance from cartilage, but I am not aware that they have been ever subjected to a microscopical examination.

When put into boiling water, they swell, become yellow, and semitransparent, and by long boiling they are dissolved and converted into gelatin, which, on evaporation and drying, becomes a firm glue. The transparency of the solution is impeded by the presence of small vessels which float in it.

If we plunge a tendon into concentrated acetic acid, it swells, becomes transparent and gelatinous. At the same time its surface becomes uneven, and is twisted in various directions, and when cut it presents an annular and angular division, owing pro-

bably to sheaths of cellular substance in the interior, and surrounding the tendinous fibres. If we now pour water upon the tendon thus altered, and make it boil, the tendon dissolves rapidly, with the exception of the small vessels, which are interspersed through it. The solution is similar to one of glue. It is not precipitated by potash nor by prussiate of potash. The same phenomena take place when tendons are treated with muriatic acid and by caustic potash.

When tendons are dried they become hard, translucent, yellow, and similar to horn; but they recover their former appearance when softened in water. A long maceration in water removes the cellular substance, and enables us to separate the tendinous fibres from each other. But if we prolong the boiling, these fibres themselves are dissolved and converted into jelly.

According to the analysis of Mulder and Scherer, the tendons consist of protein combined with three atoms of ammonia, one atom of water, and seven atoms of oxygen.

The tendons fix the muscles to the bones, and their fibres are interlaced with those of the periosteum, a membrane which seems to possess the same characters as the tendons. At least, like them, it is converted by boiling into gelatin.

Aponeuroses are a kind of sheaths which inclose one or more muscles, to which they serve as a kind of support, and of which they increase the strength. Their tissue is similar to that of tendons; they possess both the characters and composition of these bodies.

CHAPTER XI.

OF LIGAMENTS.

Ligaments are strong bands which bind the bones together at the joints. Their form and size vary considerably in different parts, some being flat bands, some rounded cords, and others lengthened tubes attached by both ends to bones which admit of free motion on one another, as we see in the capsular ligaments of the hip and shoulder. Most ligaments enter into the formation of joints, and are therefore articular; though some, as the interosseous ligaments in the fore-arm and leg, merely fill up spaces.

As far as their chemical constitution is concerned, they may be divided into two classes: One class, destined to oppose a great resistance, becomes transparent when boiled, and is gradually converted into gelatin. The ligaments belonging to the second class are very elastic. This elasticity supplies the place of muscular action, by enabling them, after being distended, to resume their primitive size and shape. To this class belongs the ligament of the neck, which supports the head of ruminating animals and horses. The ligaments which draw back the claws in the animals belonging to the genus *felis*, and also the yellow ligaments placed in man between the vertebræ, belong to the same class. Anatomists were of opinion that these ligaments were of the same nature as the fibrous membranes of the arteries; and this opinion has been confirmed by the experiments of Berzelius.

He found that when the yellow intervertebral ligaments are heated they undergo a sort of semifusion. They swell up, and after complete combustion leave a small quantity of white ash, consisting principally of phosphate of lime. When these ligaments are boiled for a long time in water, during twelve or sixteen hours for example, they do not become in the least soft, nor do they undergo any alteration; yet the water extracts a small quantity of gelatin, derived, doubtless, from the cellular substance mixed with the ligament. The ligament itself is neither dissolved nor softened, though kept for weeks in contact with alcohol, ether, or concentrated acetic acid.

But it is dissolved slowly, without the application of heat, by sulphuric, nitric, and muriatic acids. And the solutions, when diluted with water, are not precipitated by potash or prussiate of potash, but they are by the infusion of nut-galls. After having been saturated by ammonia and evaporated to dryness, the muriatic acid solution leaves a matter soluble both in water and in alcohol. The precipitate from the aqueous solution by infusion of nut-galls is almost all soluble in boiling water and in alcohol.

The solution in acids takes place much more rapidly when they are diluted and gently heated. The substance behaves in the same way with caustic potash. When this last solution is heated it gives the smell of dissolved horn. Acetic acid throws down from it a very slight precipitate. The matter which remains after the saturated potash solution is evaporated to dryness is soluble both in alcohol and water, and exhibits the same cha-

racter as that from the muriatic solution. All these reactions are the same as those of the fibrous coat of the arteries.

CHAPTER XII.

OF CELLULAR SUBSTANCE.

THE name *cellular substance* or *tissue* is given to a tissue spread through the whole body, enveloping all the organs, and filling up all the interstices, so as to leave no vacuities in the body. It is made up of pale elastic and extremely fine filaments interwoven in different ways, so as to form areolæ or spaces of various size and figure, and calculated to contain such fluids as may be deposited within them.

The quantity found in different parts varies considerably. In some parts we trace it in the form of a thin layer lying beneath the skin, and dipping into the interstices between the muscles. It is accumulated in considerable quantity in the flexures of the joints, filling up the popliteal space, the axillæ, and surrounding the vessels at the groin. In the cavity of the abdomen a large deposite is found, usually about the kidneys; and in the pelvis a loose spongy web fills up the spaces between the reflection of the serous membrane and the different viscera. It may be said that the cellular tissue of each region is continuous with that deposited in the neighbouring parts, and therefore forms a continuous whole throughout the system.

The general opinion of anatomists at present is that the cellular tissue is made up of cylindrical filaments, crossing in various ways, so as to form a net-work. These filaments in most places are aggregated together so as to constitute lamellæ, enclosing spaces or cells, which present an infinite variety of forms and of size; but which still freely communicate, as is evident from what happens in anasarca, and by the diffusion of air over the body in some cases of empyema.

The cellular tissue may be divided into two species. The first species is more dense, and shows distinct cells. It is found in the organs furnished with mucous membranes, the adhering face of which it covers. The blood-vessels and nerves are also enveloped in it. The second species is softer, and contains cells

which communicate with each other. It fills up all the interstices and penetrates into the muscles.

The cellular tissue consists of a matter which, when boiled in water, becomes soft and mucilaginous, and is at last converted into gelatin.

The cells of the cellular tissue are always moistened by a liquid secreted for the purpose; and which in a state of health is absorbed as fast as it accumulates. But in the disease called *anasarca* or general dropsy this liquid is secreted probably in greater abundance than in a state of health, while the absorbents either cease to act, or act imperfectly. Hence the liquid accumulates, fills all the cells, and constitutes the disease called *dropsy*. In such cases it may be drawn off in considerable quantities. It has been repeatedly subjected to a chemical examination. The result of these analyses will be given in a succeeding chapter of this work, while treating of *lymph*, to which liquid it obviously belongs.

In some parts of the body the cells of the cellular tissue are filled with *fat*. This is the case immediately under the skin, constituting what is called the *adipose tissue*. Many anatomists, however, consider the fat as enclosed in separate and shut vesicles, which have no communication with each other. This opinion is founded on the well known fact, that the fat of the spermaceti whale is fluid, yet it does not collect in the lowermost cells of the cellular tissue, as it would do if the cells or vesicles containing it had a communication with each other like the cells of the cellular tissue. Raspail even affirms that he can demonstrate the vesicles in which the fat is contained. Obesity is considered by some physiologists as a disease analogous to anasarca, with this difference, that the cellular tissue is filled with *fat* instead of *lymph*.

CHAPTER XIII.

OF THE SKIN.

The skin is that strong thick covering which envelopes the whole external surface of animals. It is composed of three parts, distinguished by different names, namely, 1. The *cutis* or true skin, which is innermost and thickest. 2. The *rete mucosum* lies

immediately over the true skin, and is a thin membrane, to which the colour of the body in man is owing. 3. The *cuticle* or *epidermis* constitutes the outermost membrane, and is that part of the skin which is raised in blisters. In this chapter we shall treat only of the *cutis* or true skin. The other two membranes will occupy our attention in the two following chapters.

The *cutis* or *corium* is a thick dense membrane composed of fibres interwoven like the texture of a hat. When it is macerated for some hours in water, and agitation and pressure are employed to accelerate the effect, the blood and extraneous matter are separated from it; but its texture remains unaltered. The fibres, after this maceration and softening, may be seen crossing in various directions so as to enclose spaces. These are of considerable size at the inner or attached surface of the membrane, where granules of fat projected into them; but gradually diminish towards the outer surface. The outer surface is not quite smooth, but studded with a number of minute projections called *papillæ*. Each papilla appears to consist of the soft sentient extremity of a nerve, enclosed within a delicate vascular plexus, possessing in some degree the properties of erectile tissue.

The cutis possesses elasticity to a certain extent, for after distension it retracts. The probability is that it resembles in its nature the cartilages and serous membranes; for when boiled a sufficient time in water it dissolves, and is converted into gelatin. If we suppose a piece of skin freed from the fat and cellular tissue, which adheres to its interior side, and from the hair, epidermis, and papillæ on its outer surface, it will contain, besides the fibrous mass of which it is composed, and the vessels which pass through it, a considerable quantity of liquid common to all the soft parts of the living body. Wienholt made a set of experiments to determine the proportion of these different substances, and states them as follows:*

Cutaneous tissue proper and vessels, .	32·53
Albumen, (liquid), . .	1·54
Extractive soluble in alcohol, .	0·83
Ditto soluble only in water, .	7·60
Water, ...	57·50
	100·00

* Berzelius, Traité de Chimie, vii. 298.

The liquid principles of the cutis may be extracted by water. If we dry the skin after this treatment it becomes yellowish, translucent, and stiff but flexible and tough. Ether extracts from it a good deal of fat. When macerated in water it recovers its original softness.' At the common temperature of the atmosphere it is insoluble in water. When boiled in water it contracts, becomes convex on the outside, thickens, becomes stiff and elastic. But if the boiling be long continued it softens, becomes mucous and translucent, and finally dissolves. The solution is muddy from minute blood-vessels suspended in it. On cooling the solution concretes into a jelly. Thus the cutis, by long boiling, is converted into *collin.* The rapidity with which the skins of different animals dissolve in boiling water is very different. The stronger, and larger, and older the animal is from which the skins were obtained, the longer do they take to dissolve, but the stronger and stiffer is the glue into which they are converted. The skins of fishes, of little birds, of the small mammalia dissolve readily. It is only necessary to keep them in water of the temperature of 77°, to be converted into a kind of jelly, which solidifies with difficulty, or remains half-liquid.

Skins are not dissolved by alcohol, ether, nor by the fixed or volatile oils, whether hot or cold. But alkalies and acids diluted to a certain point convert them into glue, even at the ordinary temperature of the atmosphere. Thus, if we steep a skin in concentrated acetic acid, it swells into a jelly, which is soluble in water. When a softened skin is steeped in persulphate of iron or corrosive sublimate, it gradually combines with the metalline salt, becomes more dense, harder, and incapable of putrefying. A similar combination takes place when they are steeped in infusion of oak-bark, or of any substance containing *tannin.*

It is from the skin or cutis of animals that leather is formed; and the goodness of the leather, or at least its strength, depends in some measure on the toughness of the hides. Those easily soluble, as seal-skins, afford a weaker leather than those which are more difficultly soluble in water. The process by which the skins of animals are converted into leather is called *tanning.* It seems to have been known and practised in the earliest ages; but its nature was unknown till after the discovery of the *tanning principle* by Seguin. "That chemist ascertained that leather is a compound of *tannin* and *skin;* that it is to the tannin that lea-

ther owes its insolubility, and its power of resisting putrefaction. The subject engaged the attention of Davy, who examined it with his usual ingenuity, and added several important facts to our former knowledge.

When skins are to be tanned, the first step of the process is to deprive them of their hair and cuticle. This is either done by steeping them in water till they begin to putrefy, or by steeping them in lime and water. The lime seems to combine with the cuticle, and to render it brittle and easily detachable from the hide. It produces the same effect upon the hair and the matter at its root. * When the hides have been steeped for a sufficient time, they are taken out, the hair, cuticle, &c. scraped off, and then they are washed in water.

After this preliminary process, the skins are subjected to different treatment, according to the kind of leather which is to be made.

The large and thick hides are introduced for a short time into a strong infusion of bark. They are then said to be *coloured.* After this they are put into water slightly impregnated with sulphuric acid, or with the acid evolved during the fermentation of barley and rye. This renders them harder and denser than they were before, and fits them for forming sole leather. Davy thinks, that, by this process, a triple compound is formed of the *skin, tan,* and *acid.* †

The light skins of cows, those of calves, and all small skins, are steeped for some days in a lixivium made by the infusion of pigeon's dung in water. This lixivium is called the *grainer.* By this process they are rendered thinner and softer, and more proper for making flexible leather. Davy considers the effect of this lixivium to depend upon the fermentation which it undergoes; for dung that has undergone fermentation does not answer the purpose ‡

After these preliminary processes, the skins are exposed to the action of the infusion of bark till they are converted into leather.

The infusion of oak bark contains two ingredients, namely, *tannin* and an *extractive.* The first is more soluble than the second. Hence, in saturated infusions, there is a much greater proportion of tannin than of extractive; whereas in weak infu-

* Davy, Journal of the Royal Instit. ii. 30. † Ibid. p. 31.
‡ Ibid. p. 32.

sions the extractive bears a greater proportion to the tannin. Davy has ascertained, that the hides extract both the tannin and extractive from the infusion, and leave nothing behind but pure water, provided they be employed in sufficient quantity. Hence, it is obvious, that both the tannin and extractive must enter into the composition of leather. The extractive gives the hide a brown colour, but does not render it insoluble in boiling water; the tannin renders it insoluble, but its colour continues whitish. Hence it is likely that the lightest kinds of leather contain little else than tannin, while the brown kinds contain both tannin and extractive, and the new compound is leather. Hence the reason of the increase of its weight.

Davy found that 100 of calf skin absorbed 64 in weight from a concentrated infusion of nut-galls, and 34 from a concentrated solution of oak bark; 17 in a dilute solution of the same bark; 34 in concentrated, and 15 in a dilute infusion of catechu. It is generally admitted that 100 parts of skin, when tanned, become 140 parts in weight.

Calf-skins, and those hides which are prepared by the *grainer*, are first steeped in weak infusions of oak bark, and gradually removed to stronger and stronger, till they are completely impregnated, which takes up from two to four months. As the weak infusions contain a greater proportion of extractive, the consequence of this process is, that the skin combines in the first place with a portion of it, and afterwards with the tannin. When saturated solutions of tannin are employed, the leather is formed in a much shorter time. This was the process recommended by Seguin; but it has been observed, that leather tanned in this way is more rigid and more liable to crack than leather tanned in the usual way. Hence it is likely, as Davy has observed, that the union of the extractive is requisite to form pliable and tough leather. Leather rapidly tanned must be less equable in its texture than leather slowly tanned, as the surface must be saturated with tannin before the liquid has time to penetrate deep. Davy has ascertained that skins, while tanning, seldom absorb more than one-third of their weight of vegetable matter.

Skins intended for sole leather are generally kept from the first in an infusion preserved nearly saturated by means of the strata of bark with which they alternate. The full impregnation requires from ten to eighteen months. It is likely, from this

process, that sole leather contains a greater proportion of tannin than soft leather. While drying, it is smoothed with a rolling-pin, and beat with a mallet, which must add considerably to its density.*

The process of *tawing* is analogous to that of tanning. By it the skins are converted into white leather, for gloves and other similar uses. The skins are cleaned in the usual way, steeped in lime-water, well scraped and beat with wooden pestles. They are then steeped in water containing bran, which undergoing the acetous fermentation, causes the skins to swell up and rise to the surface. They are pushed down again, and the operation is repeated till the skins cease to rise. They are then washed, well scraped, and for every hundred large sheep-skins, eight pounds of alum and three pounds of common salt are put into water. These two salts decompose each other. Sulphate of soda is formed, and chloride of aluminum; the last of which is imbibed by the skins, and combines with them. Along with the alum and salt is mixed with the water, while luke-warm, twenty pounds of the finest wheat-flour, with the yolks of eight dozen of eggs, all of which is formed into a paste a little thicker than children's pap. A quantity of hot water is put into a trough, and two spoonfuls of the paste with it, to do which they use a wooden spoon, containing just as much as is required for a dozen of skins, and when the whole is well mixed with the water, two dozen of skins are plunged into it. Care must be taken that the water be not too hot; otherwise the skins are spoiled.

After the skins have lain some time in the trough, they are taken out one by one with the hand, stretched out and well beaten with wooden pestles. They are then left five or six days in a vat, and hung out to dry on cords or racks, and the sooner they are dried the better. Such are the most material parts of the process of tawing, which consists essentially in combining the skins with alumina, or more probably with dichloride of aluminum. Leather thus made is soft, pliable, and white.

* See Davy on the preparation of Skin for Tanning. Royal Instit. Jour. ii. 30.

CHAPTER XIV.

OF THE EPIDERMIS.

THE *epidermis* or *cuticle* is the outer layer of the skin. Though very thin in most parts, it becomes thick and indurated in the soles of the feet, or wherever it is habitually subjected to pressure.* Its inner surface is smooth and uniform, being connected with the *rete mucosum* and corium by delicate filaments. But it can be readily separated from them by decoction or maceration in water. The outer surface presents in some places a number of waving excentric lines, which make it appear, when examined with a glass, ragged and uneven. It does not appear to be composed of scales, as some anatomists have supposed; but rather to be a homogeneous membrane destitute of vessels and nerves, and deposited on the skin as an insensible investment. It is slightly elastic, and is easily ruptured. It wears away pretty rapidly from all exposed parts, but is soon reproduced, and gradually acquires its original thickness.

If we heat a portion of the cuticle in the flame of a candle it melts without bending or swelling up, then catches fire, and burns with a clear flame, giving out the usual smell of burning animal matter. It imbibes water with facility. When the cuticle of the palm of the hand is kept long in water, it swells up, becomes wrinkled, opaque, and white. When left long in water, it becomes brittle without putrefying; but how long soever we boil it in water it does not dissolve in that liquid.

If we let fall a drop of binoxide of hydrogen on any part of the epidermis, it gives it a white colour, which disappears in a few hours. The cuticle is insoluble in alcohol and ether, but these liquids dissolve a small quantity of fatty matter, which the epidermis in its natural state contains. Concentrated sulphuric acid softens and gradually dissolves the cuticle. If we remove the acid before it has dissolved the epidermis completely, it leaves a dark brown spot. The part thus affected gradually becomes hard and a new epidermis forms below it. When a piece of epidermis is plunged into sulphuric acid, it becomes transparent before it dissolves. Nitric acid softens it, and if we saturate the excess of acid with ammonia, the stain acquires an orange colour,

which continues till the portion of cuticle thus affected comes off, a new portion being formed under it.

It is very easily dissolved in the caustic alkalies, even when very dilute. The alkaline carbonates do not attack it. The alkaline sulphurets give it a dark-brown almost black colour, and the stain is not removed until the cuticle is renewed. The chloride of gold tinges it purple. Nitrate of silver stains it a chalky white, which on exposure to the light becomes gradually black. If the recent stain before becoming black be washed with caustic ammonia, the greatest part of the silver may be removed. Parabanic acid and several other preparations from uric acid stain it of a beautiful crimson colour.

Mr Hatchett has drawn as a conclusion from the characters of the epidermis that it is quite analogous in its nature to coagulated albumen. How far this conjecture is correct can only be determined by an ultimate analysis.

According to John,* the epidermis of the foot is composed of,

Indurated albumen,	93 to 95
Mucus with trace of animal matter,	5
Lactic acid, Lactate of potash, Phosphate of potash, Chloride of potassium, Sulphate of lime, Ammoniacal salt, Phosphate of lime, Manganese ? and iron	
Soft fat,	0·08

The epidermis of a woman affected with herpes was composed of,

Indurated albumen,	92 to 93
Mucus,	7 to 6
Lactic acid and the above stated salts,	1
Soft fat,	0·75 to 1

Dr Scherer subjected to analysis a portion of the epidermis of the sole of the foot.† It was well washed with water, and then boiled in alcohol and ether. When burnt it left one per cent. of ashes. Abstracting the ashes its constituents were,

* Annals of Philosophy, ix. 55. † Ann. der Pharm. xl. 54.

Carbon, .	50·894
Hydrogen, .	6·781
Azote, .	17·225
Oxygen, } Sulphur, } .	25·100
	100·

He represents its constitution (abstracting the sulphur) by the formula $C^{48}\ H^{39}\ Az^{7}\ O^{17}$. If we calculate from this formula we get,

48 carbon, .	= 36	or per cent.	51·34
39 hydrogen,	= 4·875	...	6·95
7 azote, .	12·25	...	17.47
17 oxygen, .	= 17·	...	24·24
	70·125		100·

If from this formula,	$C^{48}\ H^{39}\ Az^{7}\ O^{17}$
we subtract protein,	$C^{48}\ H^{36}\ Az^{6}\ O^{14}$
there will remain, .	$H^{3}\ Az\ O^{3}$

which is an atom of ammonia + three atoms of oxygen.

CHAPTER XV.

OF THE RETE MUCOSUM.

This name has been applied by anatomists to a glairy exudation between the corium and cuticle, adhering to both, but particularly to the former. It is easily demonstrated in negroes; but much more difficultly in white men. On this account Bichat and some other anatomists have denied its existence altogether. But, on an attentive examination, it can generally be detected. It was Malpighi who first drew the attention of anatomists to this substance. He distinguished it from its appearance by the name of *mucous body;* and considered it as composed of soft fibres so arranged as to form a net-work. Hence the origin of the term *rete mucosum.* When a blister has been applied to the skin of a negro, if it be not very stimulating, the cuticle alone

will be raised in about twelve hours. After it is detached the exposed surface appears covered with a dark coating. But if the blister has been very active, another layer of a black colour comes away with it. This is the rete mucosum, which gives to the different races of men their various shades of colour.

The nature of this substance has not yet been determined. Neither nerves nor blood-vessels have been traced into it. It has been considered as a semifluid deposit or secretion. Some suppose it to contain a black matter in the negro, similar to the pigmentum nigrum of the eye. But the only chemical fact connected with it that we know is inconsistent with this supposition. Chlorine deprives it of its black colour, and renders it yellow. A negro by keeping his foot for some time in water impregnated with chlorine gas, deprived it of its black colour and rendered it nearly white; but in a few days the colour returned again with its former intensity.* This experiment was first made by Dr Beddoes on the fingers of a negro.†

CHAPTER XVI.

OF HAIR AND FEATHERS.

These substances cover different parts of animals, and are obviously intended by Nature to protect them from the cold. For this, their softness and pliability, and the slowness with which they conduct heat, render them peculiarly proper.

1. *Hair* is usually distinguished into various kinds, according to its size and appearance. The strongest and stiffest of all is called *bristle:* of this kind is the hair on the backs of hogs. When remarkably fine, soft, and pliable, it is called *wool;* and the finest of all is known by the name of *down.* But all these varieties resemble one another very closely in their composition.

Hair appears to be a kind of tube covered with a cuticle. Its surface is not smooth, but either covered with scales or consisting of imbricated cones. Hence the roughness of its feel, and the disposition which it has to entangle itself, which has given origin to the processes of *felting* and *fulling.* It is constantly in-

* Fourcroy, ix. 259.   † Beddoes on Factitious Airs, p. 45.

creasing in length, being protruded from the roots, and seems at first to be soft or nearly gelatinous. Every hair is a tube containing a delicate organ, which supplies the hair with the requisite degree of moisture. In certain diseases, as the *plica polonica*, this membrane swells so much that when the hair is cut, a liquid, and even sometimes blood exudes. In their natural state, the hairs are dry and insensible, and do not alter their appearance by keeping.

When hair is boiled in water, a portion is dissolved. This portion gelatinizes on the water cooling, and possesses the characters of gelatin. Hair thus treated becomes much more brittle than before. Indeed, if the process be continued long enough, the hair crumbles to pieces between the fingers. The portion insoluble in water possesses the properties of coagulated albumen.

Mr Hatchett has concluded from his experiments, that the hair which loses its curl in moist weather, and which is the softest and most flexible, is that which yields its gelatin most easily; whereas strong and elastic hair yields it with the greatest difficulty, and in the smallest proportion. This conclusion has been confirmed by a very considerable hair-merchant in London, who assured him that the first kind of hair was much more injured by boiling than the second.

Though hair be insoluble in boiling water, Vauquelin* obtained a solution by raising the temperature of the liquid in a Papin's digester. If the heat thus produced was too great, the hair was decomposed, and ammonia, carbonic acid, and an empyreumatic oil formed. Sulphuretted hydrogen is always evolved, and its quantity increases with the heat. When hair is thus dissolved in water heated above the boiling point, the solution contains a kind of bituminous oil, which is deposited very slowly. This oil was black when the hair dissolved was black, but yellowish-red when red hair was employed.

When the solution is filtered to get rid of this oil, the liquid which passes through is nearly colourless. Copious precipitates are formed in it by the infusion of nut-galls and chlorine. Silver is blackened by it, and acetate of lead precipitated brown. Acids render it turbid, but the precipitate is redissolved by adding these liquids in excess. Though very much concentrated by evaporation, it does not concrete into a jelly.

* Nicholson's Journal, xv. 141.

Water containing only four per cent. of potash dissolves hair, while hydrosulphuret of ammonia is evolved. If the hair be black, a thick dark-coloured oil, with some sulphur and iron remains undissolved; if the hair be red there remains a yellow oil, with some sulphur and an atom or two of iron. When acids are dropped into this solution, they throw down a white matter, soluble in an excess of acid.

Sulphuric and muriatic acids become red when first poured on hair, and gradually dissolve it. Nitric acid turns hair yellow and dissolves it, while an oil separates, which is red or black according to the colour of the hair dissolved. The solution yields a great deal of oxalic acid, and contains, besides, bitter principle, iron, and sulphuric acid. Chlorine first whitens hair, and then reduces it to a substance of the consistence of turpentine, and partly soluble in alcohol.

When alcohol is digested on black hair, it extracts from it two kinds of oil. The first, which is white, subsides in white shining scales as the liquor cools; the second is obtained by evaporating the alcohol. It has a greyish-green colour, and at last becomes solid. From red hair alcohol likewise separates two oils: the first white, as from black hair, and the other as red as blood. When the red hair is deprived of this oil, it becomes of a chestnut colour. Hence its red colour is obviously owing to the red oil.

When hair is incinerated, it yields iron and manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and a considerable portion of silica. The ashes of red hair contain less iron and manganese: those of white hair still less; but in them we find magnesia, which is wanting in the other varieties of hair. The ashes of hair do not exceed 0·015 of the hair.

From the preceding experiments of Vauquelin, we learn that black hair is composed of the nine following substances:

1. An animal matter constituting the greatest part.
2. A white solid oil, small in quantity.
3. A greyish-green oil, more abundant.
4. Iron; state unknown.
5. Oxide of manganese.
6. Phosphate of lime.
7. Carbonate of lime, very scanty.
8. Silica.
9. Sulphur.

The colouring matter of hair appears from Vauquelin's experiments to be an oil. The oil is blackish-green in black hair, red in red hair, and white in white hair. Vauquelin supposes that sulphuretted iron contributes to the colour of dark hair; and ascribes to the presence of an excess of sulphur the property which white and red hair have of becoming black with the oxides of the white metals. The sudden change of colour in hair from grief, he thinks, is owing to the evolution of an acid.*

Vauquelin considers the animal matter of which hair is chiefly composed as a variety of inspissated mucus; but some of its properties, especially its copious precipitation by tannin, do not well agree with that supposition. It seems to approach more closely to coagulated albumen, as Hatchett has shown.

When hair is heated it melts, swells up, and gives out the odour of burning horn. It burns with a strong flame, giving out a great deal of smoke, and leaves a bulky charcoal. When distilled *per se*, it gives one-fourth of its weight of empyreumatic oil, water holding ammonia in solution and much inflammable gas escapes, in which the smell of sulphuretted hydrogen may be recognized. The charcoal remaining amounts to about one-fourth of the weight of the hair. Different metalline salts produce the same change of colour on white hair as they do upon the cuticle. We can dye white hair *black* by a solution of nitrate of silver in ether. But the best way of effecting that object is to triturate the nitrate of silver with slacked lime, and to make it up into a paste with hog's lard, which may be applied to the hair without touching and blackening the skin. Another substance commonly used to dye white hair black is protoxide of lead in fine powder. One part of it is triturated with four parts of slacked lime, and a weak solution of potash. A compound of oxide of lead and potash is formed, which gradually penetrates the hair, and sulphuret of lead is formed, which tinges the hair black.

Dr Scherer subjected the hair of the beard to a chemical analysis.† It was first washed with water, and then boiled in alcohol and ether. Thus prepared, it left when burnt 0·72 per cent. of ashes. Its constituents were

* Nicholson's Journn. xv. 141. † Ann. der Pharm. xl. 55.

Carbon,	.	50·417
Hydrogen,	.	6·655
Azote,	.	17·936
Oxygen, } Sulphur, }		24·992
		100·000

He represents the constitution by the empirical formula $C^{48} H^{39}. Az^{7} O^{17}$. If, from this formula, we subtract that for protein, $C^{48} H^{36} Az^{6} O^{14}$, there will remain $H^{3} Az + O^{3}$, or an atom of ammonia, and three atoms of oxygen.

Wool has not yet been subjected to a rigid examination; but, from the experiments made on it by Berthollet, there is reason to conclude that its chemical qualities do not differ much from those of hair. When growing upon the sheep it is enveloped in a kind of soapy matter, which protects it from the attack of insects, and which is afterwards removed by scouring. Vauquelin has examined this matter, and found it to consist of the following ingredients: 1. A soap of potash; 2. Carbonate of potash; 3. A little acetate of potash; 4. Lime; 5. A very little muriate of potash; and, 6. An animal matter.*

2. *Feathers* seem to possess very nearly the same properties with hair. Mr Hatchett has ascertained that the quill is composed chiefly of coagulated albumen. Though feathers were boiled for a long time in water, Mr Hatchett could observe no traces of gelatin.

Dr Scherer purified wool by washing it in water and then boiling it in alcohol and ether.† It left 2 per cent. of ashes. Being subjected to an ultimate analysis, it gave

Carbon,	.	50·653
Hydrogen,	.	7·029
Azote,	.	17·710
Oxygen, } Sulphur, }		24·608
		100·

So that its composition is the same as that of hair. Feathers were also subjected to an ultimate analysis by Dr Scherer.‡

* Ann. de Chim. xlvii. 267. † Ann. der Pharm. xl. 58.
‡ Ann. der Pharm. xl. 61.

They contained 1·8 per cent. of ashes. The constituents obtained were

1. Of the soft downy portion.

Carbon,	50·434 and 52·470
Hydrogen,	7·110
Azote,	17·682
Oxygen,	24·774
	100·000

2. The quill portion.

Carbon,	52·427
Hydrogen,	7·213
Azote,	17·893
Oxygen,	22·46
	100·000

The constitution of both is obviously the same. Scherer represents it by the formula $C^{48} H^{39} Az^{7} O^{16}$. By this formula they contain an atom less of oxygen than hair or horns.

CHAPTER XVII.

OF HORNS, NAILS, AND SCALES.

Horns are well-known bodies attached to the foreheads of oxen, sheep, and various other animals, and are obviously intended for weapons of defence. They cover an elongation of bone which rises from the *os frontis.* The portion of horny matter nearest the forehead is the thinnest, and it constantly increases in thickness as it advances to the extremity, where it is thickest. It is translucent, and when very thin, has even a degree of transparency, and has been used as a substitute for glass in windows. Its colour is sometimes yellowish-grey, and sometimes almost black. It is capable of receiving a good polish, and its lustre is resinous.

It is not very hard, and is easily rasped down by a file or rasp. During this process it emits a disagreeable smell. When heated a little above 212°, it becomes very soft, without undergoing de-

composition, so that it can be squeezed into a mould and wrought into various forms, as is well known. When horns are distilled *per se* they give out a great quantity of fetid oil, a little carbonate of ammonia, together with a minute quantity of water. The charcoal remaining in the retort amounts to about one-sixth of the weight of the horns distilled. It has a semi-metallic lustre, and when burnt leaves a quantity of white ashes constituting about half a per cent. of the weight of the horns. It consists of phosphate of lime with a little carbonate of lime and phosphate of soda.

Horn is insoluble in water; but when boiled for several days in that liquid, it is softened, and the water is slightly precipitated by chloride of tin, but not by tannin. When horn is strongly heated with water in a Papin's digester, it is said to be converted into a gelatinous mass which possesses the properties of gelatin. Horn is insoluble in alcohol and ether. These liquids, however, separate a small quantity of fatty matter.

Concentrated sulphuric acid, at the temperature of 57°, does not dissolve horn nor acquire any colour from it. But the horn is softened by the acid. If we wash it with water, and then boil it in that liquid, a portion of it is dissolved, and the liquid is precipitated by corrosive sublimate and infusion of nut-galls. Dilute nitric acid softens horn; but a long maceration is required before this effect is produced. If we pour ammonia on the softened horn it becomes first reddish-yellow, then blood-red, and finally dissolves into a dark-yellowish red liquor. If we wash horn softened by nitric acid with cold water, and then boil it in a new quantity of water, it dissolves, forming a yellow liquid, which gelatinizes on cooling. This jelly is dissolved by cold water, and the solution is precipitated by tannin. Concentrated nitric acid dissolves horn. If we evaporate the solution to dryness, it detonates. Horn is not softened when macerated in concentrated acetic acid. But when it is digested for some days in a close vessel in dilute acetic acid, that liquid dissolves a portion of it without becoming coloured, and when the liquid is evaporated to dryness, a light-yellow substance remains, which is transparent, and not soluble in water.

If, after freeing horn from fat by means of alcohol, we dry it, and pour over it concentrated muriatic acid, after an interval of a day or two it becomes blue, though the acid acquires no colour.

Nitric acid changes the blue colour to yellow, and ammonia to orange.

The caustic fixed alkalies dissolve horn easily; but ammonia does not attack it.

If, after freeing horn from fat by means of alcohol, we place it in contact with very dilute caustic potash, the liquid acquires a disagreeable smell, and the horn assumes the form of a jelly, and gradually dissolves. The liquid is pale-yellow, and can hardly be filtered. When a concentrated solution of caustic potash is poured upon raspings of horn a very disagreeable smell is evolved, and the raspings gradually soften into a matter like glue, grey-coloured and semitransparent. The alkaline liquid has a deep-yellow colour, and gives traces of ammonia. The viscid mass is a combination of the horn with the potash. It is insoluble in the concentrated alkaline liquor while cold; but dissolves in it when assisted by heat. We pour the alkaline ley from the viscid mass, and wash it with cold water. Thus treated, it dissolves in water without communicating any colour. The solution has an alkaline reaction. When acetic acid is poured into it in such quantity as not to decompose it completely, a white curdy precipitate falls, which soon collects into a viscid gluey mass. It is a compound of horn with a minimum of alkali. If we decant off the saline solution which floats over it, and then pour water on it, it gradually gelatinizes, and at last dissolves into a mucilage decomposable by acids. If, on the contrary, we add enough of acetic acid to decompose the whole compound of horn and potash, and to leave a surplus of acid in the liquid, a precipitate falls quite similar to the former in appearance, but which is a compound of horn and acetic acid. It is insoluble in water, whether cold or hot, and also in alcohol. But it is soluble in acetic acid. Prussiate of potash throws down from this solution semitransparent flocks, which subside very slowly to the bottom of the vessel. Carbonate of ammonia gives a precipitate soluble in a great excess of the reagent. Corrosive sublimate, acetate of lead, persulphate of iron and tannin, throw down abundant precipitates.

If we evaporate the acetic acid solution to dryness, we obtain a yellow, transparent, hard, and viscid mass, which is insoluble in water. When we evaporate to dryness the solution precipitated by acetic acid, and digest the residue in water, a portion of horn

remains, but the liquid contains a little, which behaves with reagents in the same way as the acid solution.

When, instead of acetic acid, we employ muriatic acid to throw down horn from potash, the precipitate obtained is more abundant, because it is less soluble in the excess of muriatic acid added. This precipitate constitutes a coherent mass; but if we wash it and then digest it in water, it dissolves and produces a milky liquor, which, by the addition of an additional quantity of acid, produces a viscid and acid precipitate.

Berzelius considers horn as a modification of fibrin. He founds his opinions on the circumstances, that its acid solution is precipitated by prussiate of potash; that horn remains dissolved in acetic acid; and that its neutral combination with muriatic acid, which is partially soluble in water, coagulates anew when an additional quantity of muriatic acid is added.

If we boil horn with a concentrated solution of potash, it softens and then dissolves, while abundance of ammonia is given out, which has a very disagreeable smell. This disengagement continues for a long time. The portion of horn not dissolved is softened, and it becomes so slippery that, if we take it out of the liquid, we can scarcely hold it in our fingers. If we wash it in cold water to remove the alkali it dissolves in the liquid without communicating to it any colour.

The solution of horn in boiling potash is thick, of a dark-brown colour, and similar to a bad potash soap. It dissolves easily in water, forming a muddy solution, which, when filtered, is pale yellow, leaving a minute quantity of deep-green powder, which Berzelius considers as sulphuret of iron. Its dark colour vanishes when the powder is exposed to the air. If we mix the alkaline liquor with an acid, carbonic acid is disengaged mixed with sulphuretted hydrogen gas. If the acid added be muriatic, after the carbonic acid is disengaged, a compound of the acid and horn, the same as described above, falls down; but in small quantity compared to that of the horn acted upon. If we digest the acid liquor from which this precipitate has fallen over carbonate of lime till it is neutralized, and then evaporate the whole to dryness, and digest the dry residue in alcohol, to dissolve the chloride of calcium, a matter remains which dissolves readily in water, to which it communicates a pale-yellow colour. When this solution is evaporated to dryness it leaves a hard transparent matter, which

may be reduced to powder with the greatest facility. The aqueous solution of this substance is precipitated by the same reagents as the acetic solution of horn. But prussiate of potash does not render it muddy unless acetic acid be previously added.

This substance is a compound of the horny matter and lime. The lime remains behind when we burn the compound. Muriatic acid throws down a precipitate from its solution in water, which is redissolved by the addition of a greater quantity of acid. Acetic acid throws down a precipitate which requires for solution a very large quantity of free acid.

It is evident from these facts that when potash is made to act upon horn, a decomposition takes place; the horn being converted into carbonic acid, ammonia, sulphuretted hydrogen, and a substance soluble in muriatic acid and water, with a minimum of alkali; while another portion of matter remains insoluble combined with an excess of muriatic acid.

Dr John, a great many years ago, made an analysis of the horns of oxen. He extracted from them the following constituents:

Indurated albumen,	90
Gelatinous albumen with osmazome ?	8
Lactic acid,	1
Lactate of potash,	
Sulphate, muriate, and phosphate of potash,	
Phosphate of lime,	
Oxide of iron, trace,	
Ammoniacal salt,	
Fat,	1
	100*

The quantity of earthy matter contained in horns is exceedingly small. Mr Hatchett burnt 500 grains of ox horn. The residuum was only 1.5 grain, and not the half of this was phosphate of lime. 78 grains of the horn of chamois left only 0·5 of residue, of which less than the half was phosphate of lime.† They consist chiefly of a membranous substance, which possesses the properties of coagulated albumen; and probably they contain also a little gelatin. Hence we see the reason of the products that are obtained when these substances are subjected to distillation.

Dr Scherer subjected the horn of the buffalo to a chemical analysis.‡ It was purified by washing it with water and boiling

* Annals of Philosophy, ix. 55. † Phil. Trans. 1799, p. 332.

‡ Ann. der Pharm. xl. 56.

it in alcohol and ether. When burnt it left 0·7 per cent. of ashes. Its constituents were,

Carbon,	.	51·578
Hydrogen,	.	6·712
Azote,	.	17·284
Oxygen, } Sulphur, }	.	24·426
		100·

He gives us an empirical formula, C^{48} H^{34} Az^7 O^{17}. So that its constitution is the same as that of hair, namely, one atom protein + one atom ammonia + three atoms oxygen.

If we precipitate an alkaline solution of hair or horn with acetic acid, sulphuretted hydrogen escapes and a precipitate falls, which is soluble in acetic acid, and possesses the characters and constitution of protein.

The *nails*, which cover the extremities of the fingers, are attached to the epidermis, and come off along with it. Mr. Hatchett has ascertained that they are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphate of lime. Water softens but does not dissolve them; but they are readily dissolved and decomposed by concentrated acids and alkalies. Hence it appears that nails agree with horn in their nature and composition. Under the head of nails must be comprehended the talons and claws of the inferior animals, and likewise their hoofs, which differ in no respect from horn.

The substance called tortoise-shell is very different from shells in its composition, and approaches much nearer to the nature of *nail;* for that reason I have placed it here. When long macerated in nitric acid, it softens, and appears to be composed of membranes laid over each other, and possessing the properties of coagulated albumen. When burnt, 500 grains of it yield three of earthy matter, consisting of phosphate of lime and soda, with a little iron.*

The *scales* of animals are of two kinds; some, as those of serpents and other amphibious animals, have a striking resemblance to horn; while those of fish bear a greater resemblance to mother-of-pearl. The composition of these two kinds of shells is very different.

* Hatchett, Phil. Trans. 1799, p. 332.

The scales of fish, as had been observed by Lewenhoeck, are composed of different membranous laminæ. When immersed for four or five hours in nitric acid, they become transparent and perfectly membranaceous. The acid, when saturated with ammonia, gives a copious precipitate of phosphate of lime.* Hence they are composed of alternate layers of membrane and phosphate of lime. To this structure they owe their brilliancy. Mr Hatchett found the spicula of the shark's skin to be similar in its composition, but the skin itself yielded no phosphate of lime.

The horny scales of serpents, on the other hand, are composed alone of a horny membrane, and are destitute of phosphate of lime. They yield, when boiled, but slight traces of gelatin; the horn-like crusts which cover certain insects and other animals appear, from Mr Hatchett's experiments, to be nearly similar in their composition and nature.

Thus it appears that these substances bear a striking resemblance to each other, being composed of a membrane which Hatchett considers as coagulated albumen. Vauquelin, however, who affirms that they dissolve in water, provided the temperature be raised sufficiently in a digester above the boiling point, considers them, on that account, rather as a species of concrete mucus than as coagulated albumen.†

CHAPTER XVIII.

OF HARTSHORN.

The horns of the buck and hart, and indeed of the whole tribe of deer, are quite different from those which have been treated of in the last chapter. They are branched, and possess the hardness of bone. From the experiments of Scheele and Rouelle, together with those of Hatchett, we know that these substances possess exactly the properties of bone, and are composed of the same constituents, excepting only that the proportion of cartilage is greater. They are intermediate, then, between bone and horn. The same remarks apply to a fossil horn

* Hatchett, Phil. Trans, 1799, p. 332.

† Nicholson's Jour. xv. 147.

found in France, and analyzed by Braconnot. He found it composed of

Silicious sand, .	4·0
Gelatin, . .	4·6
Bitumen, . .	4·4
Oxide of iron, .	0·5
Alumina, . .	0·7
Phosphate of magnesia, .	1·0
Water, . .	11·0
Carbonate of lime, .	4·5
Phosphate of lime, .	69·3
	100·0 *

CHAPTER XIX.

OF SEROUS MEMBRANES.

THE name *serous membranes* is applied to certain thin, pellucid, and transparent tissues, which constitute shut sacs without inlet or other interruption of continuity. They are called *serous*, because they are constantly moistened by a thin albuminous fluid, supposed to resemble the serum of blood. These serous membranes in the human body are chiefly the following: 1. The *arachnoid* membrane, which invests the brain, and which is prolonged over the spinal chord: 2. The two *pleuræ*, which invest the lungs; 3. The *pericardium*, which incloses the heart; 4. The *peritoneum*, which is reflected over the different viscera of the abdomen, together with the two processes which extend from it upon the *testes*; 5. The membrane which lines the *anterior chamber* of the *eye*. Perhaps the lining coat of arteries and veins may also be referred to the serous membranes.

These membranes *invest* the viscera, which they inclose, and are likewise *reflected* upon the walls of the cavity. It is the investing part of the serous membranes that gives to different organs their shining appearance; and as the membrane is very thin and transparent, the colour, form, and even the minute in-

* Gehlen's Jour. second series, iii. 49.

equalities in the surface of these organs may be distinctly seen through the serous membranes that invest them.

Serous membranes are capable of very considerable distension, as is obvious in dropsy and in the various herniæ of the intestines. In their natural state they are insensible or nearly so; but when they are inflamed, acute pain is felt in them. As they pass from one viscus to another, it is obvious that they must form folds; and these folds have been often distinguished by names, as *omentum, mesentery, mesocolon, mediastinum,* &c.

Blood-vessels may be seen entering into the serous membranes in cases of inflammation. Hence it follows that they are supplied with arteries and veins. Whether they possess exhalent vessels to throw out the serum or lymph with which they are moistened, has not been ascertained.

As to the chemical nature and properties of the serous membranes, no experiments, so far as I know, have hitherto been made upon the subject. It is stated in chemical books that when boiled in water they are converted into *collin.* Hence it has been inferred that they are merely inspissated cellular membrane. But I am not aware of any person having tried the experiment. It is certain that the small intestines may be boiled for a long time without being deprived of their outer serous coat, and without that coat undergoing any sensible change.

The liquid exhaled from the surface of the serous membranes will be described, and its constituents stated in a succeeding chapter of this work when treating of *lymph.*

CHAPTER XX.

OF MUCOUS MEMBRANES.

THE *mucous membrane,* in an anatomical point of view, may be considered as one continuous membrane prolonged from the integuments into the interior of the passages of the body, where it serves a corresponding purpose with the skin; but which, from the nature of the fluid which it secretes, and which covers it, has received the name of *mucous membrane.* From the lips and nostrils it extends along the whole length of the alimentary canal as well as into the different follicles and excretory ducts which open

into it. The *larynx*, *trachea*, *bronchiæ*, and *air-cells* of the lungs are lined with mucous membrane. A similar mucous surface may be traced from the opening of the urinary canal along the *urethra*, *bladder*, and *ureters*, to their termination in the *calyces* of the *kidney*; also into the *vasa deferentia*. In the female it is prolonged from the vagina into the uterus and the Fallopian tubes to their termination.

Between these two great divisions of the internal integuments no organic connection exists. Each may be viewed as a canal of considerable extent, but presenting numerous contractions and dilatations corresponding with those of the hollow organs which they line. Their external surface is rough and flocculent, being attached by cellular tissue to the contiguous textures. The firmness of this attachment varies in different places. In the stomach the mucous membrane is easily separated. From the pylorus to the ileo-cæcal valve it gradually becomes more firmly attached, and in the large intestines it adheres very closely to the next coat below it till towards the extremity of the rectum, where it is again loose.

The thickness of this membrane is equally various. It is thickest in the stomach and duodenum, and thence diminishes gradually towards the lower part of the small intestines. At the ileo-cæcal valve it increases somewhat, and in the large intestines it is only about half as thick as in the stomach; but it increases towards the extremity of the rectum. Its firmness and power of resistance is greatest in the stomach.

The colour of the mucous membrane varies in different parts of its extent. It is influenced also by the age of the individual, and doubtless by the disease of which he died. When freed from cellular tissue and mucus it is translucent and white, or grayish, with a delicate rosy tinge. This tinge is owing to the blood-vessels with which it is supplied. It deepens in the stomach during the digestive process, doubtless because the quantity of blood conveyed to it is then greatest.

The *plicæ* and *valvulæ conniventes* of this membrane are well-known to anatomists. When viewed with a microscope it is found covered with a vast number of minute downy processes, giving it a flocky appearance. These have been called *villi*. These villi are generally considered as ducts which secrete the gastric juice when it is required for the purpose of digestion.

The mucous membrane, though apparently a continuation of the skin, differs entirely from that tissue in its chemical properties. It is quite insoluble in water. When long boiled in that liquid it becomes hard and brittle. Acids easily destroy it, and convert it into a pap. It readily putrefies, and in that way its texture is speedily destroyed. If we soften it in cold water, and leave it in that state to the action of the atmosphere, it is converted into a reddish mucous-looking substance before the other coats of the intestines have begun to be affected.

The mucous membrane, like the *cutis*, is covered by a very thin epidermis, to which the term *epithelium* has been applied. The chemical nature of this membrane has not been determined; but it is probably of the same nature with the epidermis.

CHAPTER XXI.

OF ARTERIES AND VEINS.

1. The term *artery** meant originally a tube containing air. It was not till after the discovery of the circulation by Hervey that their use was fully understood. They are tubes which convey the blood from the heart to every part of the body, in order to supply the waste of the system; while the *veins* convey back again to the heart all the blood which has not been consumed by the different processes going on in every part of the body.

An artery is a cylindrical and highly elastic tube, composed of three coats placed one within the other. The external coat is formed of the cellular tissue, into which it may be resolved by maceration. Its texture is closer when it is in contact with the middle coat, than externally when it is somewhat loose and flocculent. It admits of considerable extension, and can retract when the cause is removed, and it is so tough as not to be divided by a hard ligature placed on the vessel, and so firm as alone to resist the impulse of the current of blood, when the other coats are divided or torn.

The internal coat not only lines the arteries, but is continued into the ventricles of the heart. It is thin, homogeneous, transparent, and so fragile as to be easily torn. It is considered by

* From *αηρ*, air, and *τηρεω*, *I contain*.

anatomists, as similar to the *serous membranes*, though I am not aware that any experiments have been made to determine the point.

The *middle* coat is the principal one, and the one to which the arteries are chiefly indebted for their peculiar characters. It consists of pale, straw-coloured fibres, coiled obliquely round the circumference of the vessels, but none of them forming a complete circle. If an artery be stretched transversely it will recoil and resume its original diameter. If elongated it will retract. We see from this that arteries are highly elastic, and this property they owe chiefly to the middle coat, which is strong and dense. When an artery no longer carries blood, as after a ligature has been applied to it, the part beyond the ligature will retract, its cavity will be obliterated, and, by an alteration in its mode of nutrition, will degenerate into a fibrous cord. This indicates a contractile power differing from mere elasticity, and has been termed *contractility of tissue.* Anatomists long ascribed muscular properties to this middle arterial coat; but the chemical properties which it possesses are incompatible with this notion.

The middle arterial coat is quite insoluble in water, even when long boiled in that liquid. When concentrated acetic acid is poured on it, it neither softens nor dissolves; nor do we obtain any solution even when we boil it in dilute acetic acid. But it dissolves with great ease in sulphuric, nitric, and muriatic acids, even when much diluted with water. The solution is neither precipitated by an alkali nor by prussiate of potash, as is the case with fibrin, and with muscular fibre treated in the same way.

The middle arterial coat is dissolved by caustic potash. The solution is colourless, but slightly muddy; and it is not precipitated by acids. If we mix together saturated solutions of the middle coat of an artery in potash, and in an acid, the mixture becomes gradually muddy, and a precipitate falls.

This middle coat, after having been purified by solution in dilute potash ley and precipitation by an acid, was subjected to analysis by Dr Scherer.* When burnt it left an ash weighing 1·7 per cent. Its constituents (abstracting the ash) were found to be

* Ann. der Pharm. xl. 51.

Carbon,	.	53·571
Hydrogen,	.	7·026
Azote,	.	15·360
Oxygen,	.	24·043
		100.000

He represents its constitution by the empirical formula,
$C^{48}\ H^{38}\ Az^{6}\ O^{16}$. If from this formula
we abstract $C^{48}\ H^{36}\ Az^{6}\ O^{14}$, the formula for pro-

tein, there will remain $H^{2}\ O^{2}$, or two atoms of water.' So that the middle coat of arteries may be represented by 1 atom protein + 2 atoms water.

II. The *veins*, like the arteries, are composed of three coats; but they are much thinner and more flaccid than the corresponding arterial coats. They are easily distended, admitting of considerable enlargement in the transverse direction. They are also susceptible of elongation, but not to the same extent as the arteries.

The external venous coat, like that of the arteries, consists of cellular tissue, but is much thinner and less firm than that of the arteries. It is very closely united to the middle coat.

The internal coat is a thin shining membrane continuous with that which lines the auricles of the heart. It is here and there thrown into folds which constitute valves. It is considered by anatomists as similar in its nature to the serous membranes; though I am not aware of any experiment to elucidate the point.

The middle coat of the veins is thinner and much more pliant than that of the arteries. It appears at first sight smooth and even in its texture and destitute of fibres. But a more careful inspection shows that it consists of fibres, chiefly longitudinal; though some few have a transverse direction.

This middle coat has nothing in common with the middle coat of the arteries. It is not elastic, and the fibres of which it is composed are muscular, at least where the *vena cavâ* approaches the heart.

CHAPTER XXII.

OF THE MAMMÆ OR BREASTS.

The *glands* are organs destined for secreting from the blood certain liquids, useful or indipensable for various purposes of the animal economy. They consist of a congeries of vessels, and cannot, therefore, be subjected to a chemical analysis with any advantage. But it may be worth while, in this and some subsequent chapters, to state shortly the structure of some of the most important glands, so far as it has hitherto been ascertained by anatomical examination.

The *mammæ* or *breasts* are two round eminences placed one at each side, on the front of the thorax, resting on the pectoral muscles. They are fully developed in females, to whom they belong, at the age of puberty. The mamma is a conglomerate gland, consisting of several small lobes, each being an aggregate of a number of lobules. Each lobule is about the size of a millet-seed, oblong in shape and hollow. It consists of a mucous lining, and an envelope of cellular tissue, in which the secreting vessels ramify. From the lobules thus formed arise the minute radicles of the lactiferous tubes, which receive the milk as it is secreted. The tubes converge towards the nipple, so as to become collected into a fasciculus beneath it, in which situation they are supported by some firm cellular tissue. The number of fasciculi varies from twelve to fifteen, and each belongs to a particular lobe of the gland. Four, six, or eight, minute ducts, unite to form one lactiferous tube, which inclines to the areola, where it dilates somewhat; but at the base of the nipple it narrows again, and runs in a straight course from its base to its summit, where it terminates. The tubes are lined throughout by a mucous membrane, which permeates the whole of their extent, and even covers the lobule. This inner lining appears to be enclosed in another tunic formed of cellular tissue.

From this description it appears that the mammæ, if we abstract the numerous vessels which cover every lobule, and which are too minute and intricate to admit of a chemical examination, are composed of cellular tissue lined with mucous membrane—and therefore similar to what has already come under our review.

CHAPTER XXIII.

OF THE PANCREAS.

THE *pancreas* is a conglomerate gland situated behind the stomach between the spleen and duodenum; one extremity being in contact with the spleen and the other surrounded by the curve of the duodenum, the left or splenic extremity is narrow and thin; the right is broader, and called the head of the pancreas. A small part of it is detached somewhat from the rest, and called the lesser pancreas.

The granules of which this gland is composed are aggregated into lobules, which are connected so as to form a mass of cellular tissue. It is of a pale-ash colour, about six inches long, and one and a-half in breadth, and from half-an inch to three quarters in thickness. Each granule contains within itself all the elements of a secreting organ. In its interior is a minute cell, being the ultimate radicle of the excretory duct, around which is a minute vascular plexus, all of which are supported and connected by cellular tissue, in which also run filaments of nerves.

Thus it appears that, if we abstract the numerous vessels and nerves which surround every granule, the pancreas consists chiefly of cellular tissue. Doubtless the pancreatic duct, even to its capillary extremities in the granules, is lined with a mucous membrane.

CHAPTER XXIV.

OF THE LIVER.

THE *liver* is a conglomerate gland of a large size, destined for the secretion of the *bile*; a liquid, the nature and properties of which will be described in a future chapter of this volume.

The form of the liver is very irregular. Its colour is reddish-brown, its upper surface is smooth and convex, and is divided into two parts or lobes. Its texture is pretty firm. It is invested by the peritoneum, except at the points of reflection of

the falx and of the lateral and coronary ligaments. Below this serous coat is a thin lamella of cellular tissue, which invests the organ in its entire extent. On the surface of the liver this lamella is very thin, but opposite to the transverse fissure it is considerably increased in quantity, encases the hepatic vessels, and accompanies them throughout their ramifications, supporting them in their course, and constituting the tissue in which the capillary vessels are ramified.

The liver is heavy, and weighs in an adult human subject about four pounds. Its transverse diameter is from twelve to thirteen inches, and its thickness from five to six inches. When torn or divided, the exposed surface presents a granular appearance, as if it were made up of minute grains or lobules.

From the recent examination of the liver by Mr Kiernan,* it seems pretty clear that it consists of a great number of small globules, each of which is made up of a reticulated plexus of four different kinds of vessels supported by cellular tissue. These vessels are, 1. The minute radicles of the biliary ducts, which divide and subdivide so as to form a mesh in the interior of the globule. 2. The terminal branches of the *vena portæ*, which convey blood to the biliary ducts, in order to secrete bile from it. 3. The minute branches of the hepatic artery, which convey blood into each of the globules, in order to supply the requisite nourishment to the parts. 4. The minute ramifications of the hepatic vein, which convey away the superfluous blood from the hepatic artery and throw it into the *vena portæ*. Besides these four sets of vessels the liver, doubtless, contains lymphatics, which add to the complexity of the structure. The nerves also of the liver serve to complete the structure of this complex organ.

From the preceding statement it is evident that the liver consists chiefly of a congeries of five different kinds of vessels connected together by cellular tissue. It is not likely that much light could be thrown on its nature by subjecting it to a chemical analysis. We have, however, two elaborate analyses of the liver. Braconnot analyzed the liver of an ox in 1819;† and Fromherz and Gugert made a similar set of experiments upon the human liver in 1827.‡ Vauquelin, as long ago as 1791, had made a set of experiments on the liver of the *skate* (*Raia batis.*)§

* Phil. Trans. 1833, p. 711.
† Ann. de Chim. et de Phys. x. 189.
‡ Scheweigger's Journ. l. 81.
§ Ann. de Chimie, x. 193.

Vauquelin showed that the liver of the skate, which is very large compared to the size of the other viscera, contains more than half its weight of a liquid fixed oil. It is well-known that a similar observation applies to the liver of the cod and of various other fishes.

Braconnot pounded a quantity of ox-liver in a marble mortar, mixed it with water, and passed the mixture through a piece of cloth of a firm texture. The greatest part passed through the cloth; but a number of minute vessels remained behind. The liquid thus filtered was muddy and somewhat milky. When heated it coagulated, and a quantity of albumen collected together at the bottom of the vessel. This precipitate was dried, reduced to powder, and digested in rectified oil of turpentine, which dissolved a portion of fatty matter, to which the milky appearance of the liquid before coagulation was owing. The oil of turpentine being distilled off, the fatty matter remaining had a reddish-brown colour, and was viscid or almost solid. Its smell and taste was similar to that of fried liver. It was insoluble in water; but soluble in alcohol of 0·833. When left long in contact with caustic soda it was converted into soap. This fatty matter, like cerebrote from the brain, contained a notable quantity of phosphorus.

When alcohol was employed to separate this fatty matter from the liver, it dissolved along with it an animal substance, which communicated to the fatty matter the property of mixing readily with water, and of forming a sort of emulsion, from which it could be precipitated by infusion of nut-galls.

The albumen freed from the fatty matter by oil of turpentine, when burnt, left phosphate of lime with a trace of iron and some sulphate of lime. From these experiments it appears that the coagulum by heat consisted of albumen, and a peculiar fatty matter containing phosphorus.

The liquid from which this deposit had fallen reddened litmus-paper. When concentrated by evaporation it deposited some additional flocks of albumen, and left, when evaporated to dryness, a brownish-yellow extractive matter, which remains soft, and cannot be completely dried. This matter resembled much the osmazome of Thenard, but wanted its peculiar taste and flavour. Potash added to it did not evolve ammonia, nor did sulphuric acid evolve the smell of acetic acid. It contained no al-

kaline lactate, as boiling alcohol did not extract any from it. Indeed that reagent dissolved very little of anything from it.

The portion insoluble in alcohol being dissolved in water and mixed with the infusion of nut-galls, let fall a precipitate, which Braconnot considered as albumen still remaining in it. The excess of tannin being removed by the peroxide of tin, the remaining liquid contained a matter, which, being evaporated, left a substance similar to a vegetable extract, and containing a little azote. Being dissolved in water, it became acid without putrefying.

Braconnot found ox-liver to be composed of the following constituents:

Vessels and membranes,	18·94
Parenchyma,	81·06
	100·00

The parenchyma contained the following substances:

Water,	68·64
Dried albumen,	20·19
Matter (containing little azote) soluble in water, and little soluble in alcohol,	6·07
Oil similar to cerebrote,	3·89
Chloride of potassium,	0·64
Ferruginous phosphate of lime,	0·47
Acidulous salt insoluble in alcohol,	0·10
Blood, a little.	
	100·00

Fromherz and Gugert analyzed the liver of a healthy young man who had been executed. Their process was as follows:

After wiping the liver clean from blood, they cut it into small pieces, and digested it in cold water till the liquor ceased to dissolve anything. The solution was slightly red, mucilaginous, and muddy. Being separated by filtration from the albumen, it was evaporated to the consistence of a syrup. It left an extractive matter, from which boiling alcohol extracted (besides extractive) a substance, which partially precipitated on cooling in white flocks. This substance Fromherz and Gugert considered as casein. But they do not mention the characters which induced them to draw this conclusion. When calcined, it left some chloride of potassium and phosphate of lime.

The alcoholic solution had a disagreeable smell, which the alcohol distilled from it retained. When evaporated to dryness, it left a dark-brown viscid mass easily soluble in water, not precipitated by acids, but by infusion of nut-galls, trisacetate of lead, corrosive sublimate, and nitrate of silver. They considered this substance as *osmazome.*

The portion from the solution in cold water which the boiling alcohol had left undissolved had a pale-yellow colour, and was soluble in water. They considered it as *salivin* mixed with a little *casein.* But they do not give us the characters which induced them to draw this conclusion.

The portion of liver which was insoluble in cold water was next treated with boiling water. The decoction had a light-yellow colour. It was evaporated to dryness, and the residue treated with hot alcohol. The alcoholic solution, on cooling, deposited some flocks of casein. It was evaporated to dryness, again dissolved in hot water, and the solution treated with trisacetate of lead. The portion thus precipitated was extractive. The portion not soluble in alcohol was gelatin.

The portion of liver left after the action of cold and boiling water was treated with boiling alcohol. A transparent light-yellow tincture was obtained, which became muddy on cooling, and gradually let fall a yellowish-white precipitate, which was separated from the liquid and digested in ether. The ether dissolved a portion of fatty matter, which crystallized in stars, and which was considered as *stearin.* The solution contained also a portion of *elain.*

The ether left a residue which possessed the following properties: It was a solid, granular, brownish-yellow mass. When dry it became hard and brittle, and had neither taste nor smell. It did not melt when heated to 212°. At a higher temperature it swelled up and burnt with flame, giving out a great deal of smoke. When distilled *per se* it gave out a very small quantity of carbonate of ammonia, probably owing to the presence of a little foreign matter. It was quite insoluble in water, insoluble in cold, but pretty soluble in boiling alcohol. It was insoluble in ether. When heated with caustic potash, it formed a clear solution, from which acids threw down white flocks. When these flocks were carefully washed with water, they were soluble in alcohol and ether, and the solution had no acid reaction.

They considered it as a resinous body, to which they gave the name of *liver resin.*

The alcoholic solution freed from the above described precipitate, being reduced by evaporation to one-fourth of its bulk, became muddy and brownish yellow, drops of oil swam upon its surface together with larger masses, which strongly reddened litmus-paper, and when the liquid cooled, partly crystallized in bundles of white needles, partly remained liquid, retaining the yellow colour. These substances were the *stearic* and *oleic* acids.

The alcoholic solution from which these two fatty acids had separated being evaporated to dryness, left a brown substance, soluble in water, which was considered as *extractive matter.*

The portion of the liver not acted on by water or alcohol was considered by these chemists as the parenchyma of the liver, and not subjected to farther examination.

The general result of the analysis of the human liver by Fromherz and Gugert was as follows: 100 parts of liver contain,

Water, .	61·79
Solid matter,	38·21
	100·00

The solid matter consists of,

Matter soluble in water or alcohol, . .	71·28
Insoluble parenchyma, .	28·72
	100·00

100 parts of dry liver were found to contain 2·634 of salts. These were chloride of potassium, phosphate of lime, phosphate of potash, with a little carbonate of lime and traces of peroxide of iron.

It is hardly necessary to observe, that such analyses of an organ so complicated as the liver, containing at least five different sets of vessels, all of them filled with bile, blood, or lymph, besides nerves and cellular tissue, cannot be expected to throw much light on its nature. It is not even likely to make us acquainted with any new animal substances.

CHAPTER XXV.

OF THE KIDNEYS.

THE *kidneys* are the important glands which separate the urine from the blood. In man they are two in number, situated close to the spine on each side of the abdomen, just opposite the lowest of the false ribs. They are almost always imbedded in a great quantity of fat. They have a reddish-brown colour, a firm feel, and are about the size of the fist or rather less. Their shape resembles that of a kidney bean. Anteriorly they are covered by the peritoneum, which may be easily detached from them. When a kidney is cut across we perceive that it consists of two different substances distinguished from each other by their colour. These from their position are called *cortical* and *medullary*.

The *cortical* substance, placed immediately under the investing membrane, occupies the entire circumference of the organ, being about two lines in thickness, and sends inwards prolongations, between which the medullary portion is placed. It has a deep-red colour, is very easily torn, and consists almost entirely of the capillary terminations of blood-vessels.

The *medullary* part consists of a series of conical masses, the bases of which are directed towards the surface of the kidney, and the small extremities towards its fissure. The cones are invested, except at their apex, by the cortical substance. The medullary substance is more dense than the cortical, and its colour is much lighter. As it is made up of a series of minute tubes, it is sometimes called *tubular substance.*

The fissure of the kidney lodges the renal artery and vein, the nerves and lymphatics, together with the commencement of the excretory duct. This duct, called the *ureter*, expands opposite to the fissure of the kidney into an irregular oval cavity called the *pelvis.* The pelvis gives off three tubes, one to each extremity of the organ, and the other to the middle opposite the fissure. Each of these tubes, again, subdivides into from seven to thirteen smaller tubes, each of which terminates in a cup-like cavity called *calyx.* Each calyx embraces the extremity of one or more rounded processes called *papillæ*; and each papilla is the summit

of a conical mass, whose base looks towards the circumference of the kidney, and is, together with the sides, as it were, imbedded in the cortical part of the kidney. The conical masses are usually more numerous than the calyces, in which they terminate. Each is composed of minute tubes, one end of which opens on the surface of the papilla, and, therefore, pours its contents into the investing calyx, while the other, prolonged to the base of the cone, is there continuous with the capillary termination of the arteries, from which it receives the urine the moment it is separated from the blood. It passes successively by the tubuli, calyces, smaller tubes or infundibula, and pelvis; whence it enters the ureter, and is conveyed to the bladder.

The pelvis is covered by a mucous membrane, which, doubtless, lines also the *tubuli uriniferi* to their minutest termination. It is probable also that the fibrous investment of the infundibulum and calyx is prolonged so as to become continuous with the fibres which constitute the tubuli.

From the preceding description it is obvious that the cortical part of the kidney is little else than a congeries of vessels and nerves connected together by cellular tissue. It is in this part that the urine is separated from the blood. The medullary portion consists of a congeries of tubes, also connected by cellular tissue, through which the urine is conveyed to the pelvis of the organ, whence it passes by the ureters into the bladder. It follows from this complicated structure that little light is likely to be thrown upon the nature of these organs by subjecting them to a chemical analysis. It would be impossible to separate the different kinds of vessels from each other, in order to examine them separately, and scarcely less difficult to free them from the liquids with which they are filled in the living animal.

Berzelius removed the serous membrane which covered the kidneys of a horse, cut the kidney itself into small pieces, and suspended them in cold water till they ceased to colour that liquid. He then put the kidney into a porcelain mortar, and pounded it with a wooden pestle. By this process it was almost all converted into a liquid, which he filtered through cloth. On the cloth remained a fibrous matter, which was kneaded in water as long as it rendered that liquid milky. The fibrous matter remaining after these processes constituted an exceedingly small portion of the kidney employed. This solid residue possessed the following properties:

It was white, and composed of fibre, and resembled exactly in appearance the fibrin of the blood. When dried it became yellow and translucent. Ether dissolved from it a fatty matter, which Berzelius considered as a mixture of stearin and elain. Water softened it, and restored its original appearance. When long boiled, it contracted and became hard. Water scarcely dissolved anything from it. Concentrated sulphuric acid neither dissolved nor decomposed it, nor did it reduce it to a jelly as it does fibrin. Nitric acid of specific gravity 1·12 dissolved it when assisted by heat, but without decomposing it. A few colourless flocks remained undissolved. The solution was pale-yellow, and when saturated with ammonia became deep-yellow, but no precipitate fell. It was neither precipitated by prussiate of potash nor by infusion of nut-galls. Concentrated muriatic acid seems at first sight not to attack the solid matter of the kidney, but it gradually assumes a violet colour, and in the course of a few days dissolves the whole of it without the assistance of heat. The solution was not precipitated by prussiate of potash, nor by ammonia. When saturated by ammonia and evaporated to dryness, the residue redissolved both in water and alcohol. It was not rendered gelatinous by concentrated acetic acid. But when digested in dilute acetic acid, it was divided into two substances, one of which dissolved in the acid, while the other remained perfectly insoluble.

The solution being evaporated to dryness, left a colourless and translucent residue. It dissolved in a little cold water, and the solution in forty-eight hours assumed the form of a jelly, which dissolved in water, leaving a mucilaginous matter, which dissolved also when the water was heated. But it was again deposited when the water cooled. The solution did not react as an acid, and had neither colour, taste, nor smell. It was not precipitated by prussiate of potash nor by acetate of lead, diacetate of lead, nor by corrosive sublimate. But infusion of nut-galls threw it down in large detached flocks, which did not unite into a coherent mass when heated.

Caustic ammonia decomposed the solid residue from the kidney, as well as acetic acid. What the alkali had dissolved remained, after the evaporation of the liquor, under the form of a colourless mass; and contained a matter soluble only in hot water, in greater quantity than existed in the acetic acid solution.

It contained besides a substance insoluble in boiling water. The aqueous solution of the dried mass had no taste, and neither reacted as an acid nor as an alkali. Even after adding to it an acid, it was not precipitated by prussiate of potash; but it was thrown down by acetate of lead, corrosive sublimate, and by the infusion of nut-galls. The portion insoluble in ammonia had not altered its appearance. Dilute caustic potash dissolved it with difficulty, or even not at all while cold. But, by the application of a moderate heat, it was slowly but completely dissolved. Acetic acid, being added in excess, precipitated the portion insoluble in that reagent.

From these reactions it follows that the solid portion of the kidney is neither fibrin nor cellular tissue. It approaches nearest to the fibrous coat of the arteries, and probably, therefore, is little else than a congeries of blood-vessels.

The liquid of the kidney separated from the fibrous matter, the characters of which have been just described, was muddy and mucilaginous, and resembled milk. When heated to nearly the boiling point it coagulated into a mass so thick that it was necessary to boil it with an additional quantity of water, in order to be able to separate the coagulum from the liquid portion. This coagulum was dried and digested in ether, which separated a considerable quantity of fatty matter. The residue when moistened with water assumed its original appearance. It was dissolved in caustic potash, and acetic acid added in great excess. The matter described above as insoluble in acetic acid was precipitated. From this it was evident that the coagulum was albumen mixed with capillary blood-vessels.

The liquid separated from the coagulum was acid. When evaporated it left a yellow extract mixed with saline crystals. Alcohol of 0·8333 dissolved from it a yellowish acid extractive matter, together with some common salt. And the matter remaining after the action of the alcohol was precisely the same as the corresponding substance obtained from the liquid expressed from muscle. It was mostly soluble in water, and the solution when evaporated left a pale yellow, transparent, hard substance, which contained phosphates. It was copiously precipitated by lime-water. What the water had left undissolved was soft, white, and semitransparent. It was soluble in hot water, from which it was precipitated by tannin.

Berzelius concludes from these experiments, that the capillary tubes of the kidneys contain a liquid very rich in albumen, and rendered acid by the presence of a little lactic acid. But that no fibrin exists in it. Berzelius attempted in vain to discover the presence of urea in the liquid from the kidneys.* But the presence of that substance has since been detected in it.

CHAPTER XXVI.

OF THE OTHER GLANDS.

BESIDES the mammæ, pancreas, liver, and kidneys, there are many other glands in the living body, destined to secret various substances for purposes connected with the welfare of the living animal or with the continuance of the species. It may be proper to notice some of the most important of these glands in the present chapter.

1. *Salivary glands.*—These glands are six in number; namely, two parotid, two submaxillary, and two sublingual; one of each on each side of the face.

The *parotid* gland, as the name implies, is placed near the ear. It extends from the zygoma to the angle of the jaw and the mastoid process. It has a pale-ash colour, and is composed of minute granules aggregated into lobules and lobes. The external surface of the gland is covered by the skin and partially by the platisma muscle, and bound down by a prolongation of the cervical fascia. The external carotid artery and vein passes through its substance, and also the fascial nerve. The chemical properties of this gland have not hitherto been subjected to examination. Nor does it seem possible to separate the glandular tissue from the numerous vessels with which it is filled.

The *submaxillary* gland lies behind and beneath the ramus of the jaw. It is separated from the parotid gland by the stylomaxillary membrane, where it is covered by the skin and platisma, and invested with a thin membrane of cellular tissue. The facial artery runs in a groove on its upper suface. Its excretory duct, called *ductus Whartoni*, terminates towards the side of

* Traité de Chimie, vii. 334.

the *frenum linguæ.* No chemical experiments have hitherto been made upon this gland.

The *sublingual gland* is much smaller than either of the preceding. It lies beneath the tongue close to the side of its frenum. Its secretion is poured into the mouth by several minute orifices, which open beneath the tongue on each side. Nothing is known concerning its chemical constitution.

2. The *testes* are two in number, and some time before birth lie on the psoas muscle near the lower extremity of the kidneys. Each of them is invested by a proper capsule, and receives, besides, a partial covering from the peritonæum. About the eighth month the testis enters the ring lying behind the process of the peritonæum, which goes out of the abdomen by the inguinal canal, and in the ninth month it is found in the bottom of the scrotum.

The testis is enclosed in a firm capsule called the *tunica albuginea.* It is of a clear white colour, dense, and fibrous, and the fibres interlace in every direction. At the posterior border it separates into two laminæ; one of which, the external, is continued to the *vas deferens.* The inner surface of the albuginea is lined by a delicate membrane formed of the ultimate ramifications of the spermatic blood-vessels, united by a little cellular tissue, and thence called *tunica vasculosa.* The testis itself, below these coverings, has the appearance of a soft, pulpy, dark yellow mass, divided into lobes. It is composed of a great number of minute tubes, called *tubuli seminiferi,* which do not communicate with each other. The lobes differ in size, some containing one, and others a greater number of seminal tubes. Their shape is somewhat conical; the large end of which is directed towards the circumference of the testis.

The seminal tubes are the vessels in which the semen is secreted. According to Monro, they are about 300 in number, the length of each is about sixteen feet, and the diameter about $\frac{1}{200}$th of an inch. Each of these small vessels commences by a closed extremity, towards the inner surface of the fibrous covering of the testis, and from this point it proceeds in a zig-zag course towards the middle of the organ. It loses its convoluted appearance when it approaches to what is called the mediastinum of the testis, and, passing through its fibres, opens into the next order of vessels.

The second order of vessels is situated in the substance of the

tunica albuginea, occupying the anterior part of the process of it called mediastinum. The blood-vessels occupy the posterior part. These vessels constitute what is called *rete testis.* Being less convoluted than the tubuli, they are called *vasa recta.* Their direction is backwards and upwards to reach the posterior and upper part of the testis. The *vasa recta* are not so numerous, but larger than the *tubuli seminiferi,* from which they receive the secretion; but they are more numerous and smaller than the vessels into which they discharge it.

These are the *vasa efferentia.* They are from twelve to fifteen in number, and open separately into a single vessel of which the epididymis is formed. This vessel or tube is very much convoluted, and the convolutions are united together by small fibrous bands. It terminates in the *vas deferens,* which is the excretory duct of the testis.

From the preceding description, it is evident that the testis is composed almost entirely of tubes and blood-vessels connected together by fibrous bands. It would be next to impossible to separate the different vessels from each other, so as to be able to examine each kind separately. And from the great minuteness and thinness of the tubes, the different coats of which they are composed cannot be recognized, far less separated from each other. We need not be surprized, therefore, that no attempt has hitherto been made to determine the chemical constitution of the testes.

3. The *lachrymal* gland is placed at the upper and outer part of the orbit, near its anterior border, corresponding with the lachrymal fossa in the orbital plate of the frontal bone. The gland is convex on its upper surface. Its under surface is concave, where it rests on the globe of the eye, the recti muscles interposing. Its length is three-quarters of an inch, its breadth half-an inch. It is divisible into two lobes, so closely connected that the line of separation is not easily seen. When stript of the cellular tissue it is observed to be composed of a number of granules, each forming a secreting structure, which produces the tears. From the granules arise excretory ducts, which emerge from the gland at its anterior border, run downwards and inwards close to the conjunctiva, and open in a row upon its free surface about three lines above the upper margin of the tarsal cartilage. These ducts are usually seven in number.

The lachrymal gland resembles the mammary and salivary glands and the pancreas, in this respect, that the ducts ramify with a certain degree of regularity, the principal trunk giving off branches laterally at certain intervals, these sending out in the same way side branches, which in their turn afford a third set. No attempt, so far as I know, has hitherto been made to determine the chemical nature of the lachrymal glands.

4. Most of the other glands are so small in size that their structure has hitherto eluded the observations of anatomists, and the researches of chemists. The glands of the *meatus auditorius externus*, which secrete the cerumen of the ear, may be mentioned as examples; also the sebaceous glands, those by which insensible perspiration and sweat are elaborated, and which, from recent observations, seem to have a form somewhat resembling a cork screw. The glands of the larynx, those that secrete mucus, those which elaborate the gastric juice, and many other minute glands, still remain unknown as far as their structure is concerned.

CHAPTER XXVII.

OF THE LUNGS.

THE *lungs* are the important organs by which respiration is performed; a function so necessary to life that it cannot be suspended even for a few minutes without death. The lungs in man and most quadrupeds are double, one lung being situated on each side of the thorax. Each lung is surrounded by the pleura, and they are separated from each other by two folds of the pleura called the mediastinum. The lungs are connected with the mouth and nostrils by a cartilaginous tube called the trachea. The upper part of this air tube, being so constructed as to constitute the organ of the voice, is named the *larynx*. It consists of cartilages, ligaments, and muscles, and is lined by a mucous membrane. Besides these there are blood-vessels and nerves, and some glands. The cartilages are the thyroid, cricoid, and the epiglottis, which shuts the mouth of the larynx, by closing down upon the *rima glottidis*, in order to prevent foreign substances from making their way into the lungs. These three are large single cartilages constituting the throat, and very con-

spicuous on the fore part of the neck. Below them are two pairs of small cartilages; namely, the arytænoid and cuneiform cartilages.

The thyroid cartilage is deficient behind, its place being supplied by a strong membrane. The cricoid cartilage makes a complete circle round the tube. The trachea is a cylindrical tube, which extends from the cricoid cartilage to the third dorsal vertebra. It is composed of fibro-cartilaginous rings, varying from sixteen to twenty in number, and of membranes which connect them. The rings do not extend all round the tube; they are wanting behind where the trachea is contiguous to the œsophagus. A thin elastic fibrous lamella forms the circumference of the tube, serving to connect the cartilaginous rings, which seem as if developed on its interior, and also to complete the circuit behind where the cartilages are wanting. Within, the trachea is lined by a mucous membrane. Where the cartilages are deficient, the mucous membrane is supported by some longitudinal fibres, and beneath these we find a series of muscular fibres, as in the intestinal canal.

At the third dorsal vertebra the trachea divides into two branches called bronchii, one of which proceeds to each lung. They are composed of the same constituents as the trachea; but the rings, as we go downwards, gradually lose their annular form, and become lamellæ of irregular shape, placed in different parts of the circumference of the canal. As the tubes pass down they subdivide into more and more branches, and at the points of subdivision they are still somewhat annular, so much so at least, as to keep the orifices open. So far as recognizable by our senses the minute bronchii seem to be composed of the same materials as the larger tubes; but reduced to the greatest degree of tenuity. These minute tubes gradually terminate in small globular vesicles, a congeries of which constitute the body of the lungs.

The external surface of the lungs is smooth and convex. They are divided into different lobes, and are covered by a thin serous membrane, a continuation of the pleura. Upon the interior surface of the small globular vesicles, in which the bronchiæ terminate, the pulmonary artery and vein ramify, so as to expose the whole blood as it passes through the lungs to the action of the air. These vesicles are doubtless coated by a continuation of the mucous membrane which lines the trachea.

From the preceding description we see that the air-tubes and lungs are composed of cartilage, fibrous membrane, and mucous membrane internally, and a serous membrane externally; besides blood-vessels and nerves. The cartilages when long boiled in water mostly dissolve, but the solution does not gelatinize, however much it may be concentrated. The serous and mucous coats are doubtless of the same nature as those in other parts of the body, and the same must be the case with the arteries, veins, and nerves. But no experiments have been made upon the fibrous membrane; though in external appearance it bears considerable resemblance to the fibrous coat of the arteries. Neither has anything been ascertained respecting the chemical nature of the tissue which connects the innumerable vesicles of which the lungs are composed with one another. The lungs themselves have a peculiar appearance, differing from that of every other part of the body, and this must be owing to the nature of the tissue which connects these vesicles together. But it would be extremely difficult, if not impossible, to examine that tissue separate from the various membranes and blood-vessels with which it is so intimately connected.

CHAPTER XXVIII.

OF THE MEMBRANES OF THE EYE.

The eye is a globular body filled internally with the aqueous humor, the lens and the vitreous humor, and surrounded externally by three or four different membranes or coats. These are the *conjunctiva*, the *sclerotic* coat, and the *cornea*; the *choroid* coat, *Jacob's membrane*, and the *retina*.

1. The conjunctiva lines the free border and inner surface of the eyelids, from which it is reflected on the globe of the eye, so as to cover its anterior third. It is red and vascular on the lids, but firm and pale on the sclerotic, and very thin and transparent on the cornea. The chemical properties of this coat have not been ascertained; but it is not unlikely that it has at least a great analogy to the *cuticle*.

2. The *sclerotic* may be considered as the true external coat of the eye, since it covers the whole of it except the small portion occupied by the cornea. It is thick, dense, and opaque.

Externally it is covered by cellular tissue and fatty matter, but its inner side is smooth and shining, with a pearly or almost silvery lustre. When boiled in water it is converted into gelatin, and is therefore similar in its nature to the skin. If we cut it into small pieces, and digest it in water, the liquid assumes a yellow colour, and holds in solution an extractive matter similar to that obtained from muscle. When the sclerotic coat thus treated is boiled in water, the jelly obtained is colourless, but contains mixed with it numerous fragments of blood-vessels. Muriatic acid causes the sclerotic coat to contract, and dissolves it rapidly when raised to a boiling temperature. No gas escapes during the solution. Acetic acid also causes it to contract, deepens the colour, and when boiled on it renders it semitransparent, though it does not dissolve it; but if we add water, and boil it, a solution takes place which gelatinizes on cooling. Potash and prussiate of potash do not precipitate this solution. Hence it follows that the sclerotic coat contains no fibrin.* The tendons of the muscles of the eye being spread upon the sclerotic coat must in some measure modify its chemical properties.

3. The *cornea* is a transparent membrane, which occupies the fore-part of the eye, and is inserted into the sclerotic somewhat as a watch-glass into a watch. It adheres firmly to the sclerotic, so that long maceration is necessary to separate them. It is composed of thin lamellæ, and in the living eye is quite transparent; but after death it acquires a grey colour and a semitransparency, and when plunged into water it becomes opaque and white like coagulated albumen. When boiled in water it swells very much, then softens, and is gradually dissolved. The solution on cooling coagulates into a jelly. It is soluble in muriatic acid. In acetic acid it swells without becoming transparent. When we digest it in acetic acid the liquid acquires the property of being precipitated by prussiate of potash. This shows that the cornea besides gelatin contains also albumen.

4. The *choroid* coat lies immediately within the sclerotic, to which it is attached by cellular tissue. It is soft and dark-coloured, loose in its texture, and consists of two lamellæ, which are separable behind, though connected before. It is essentially vascular in its structure, being composed of minute arteries and veins united by cellular tissue. The veins, for the most part,

* Berzelius, Traite de Chimie, vii. 449.

occupy the external, and the arteries the internal surface of the choroid. From this account, it is obvious that when this coat is boiled in water, the cellular tissue will be converted into glue, while the veins and arteries will remain undissolved.

5. Within the choroid, and next the vitreous humour, with which it is merely in apposition, lies the *retina*, which is an expansion of the optic nerve. It is a soft and pulpy membrane. In the living eye it is transparent, but a few hours after death it becomes of a pale-white colour. According to Lassaigne, who analyzed it, its constituents are the same as those of the medullary part of the brain. But it contains scarcely $\frac{1}{100}$th of fatty matter, one portion of which contains phosphorus, and cannot be saponified, while the other is capable of being converted into a soap like common fat. The retina contains

Water,	92·9
Albumen,	6·25
Fat,	0·85
	100·0

While the optic nerve contains

Water,	70·36
Albumen,	22·07
Cerebrote and fat,	4·40
	96·83

6. The *pigmentum nigrum* is spread upon the choroid, by the inner membrane of which it appears to be secreted. It is easily obtained by washing the choroid coat (freed from the retina) in water as long as that liquid is discoloured. It remains long suspended in water, and then appears of a deep-brown colour. But it may be collected on the filter, and then constitutes a black coherent mass. This substance was examined chemically by Berzelius, and some years after by Leopold Gmelin.

Berzelius found it insoluble in water both cold and hot. It was also insoluble in alcohol and in dilute nitric and muriatic acids, as also in concentric acetic acid. Yet these acids assume a shade of yellow. Dilute potash ley dissolves it with difficulty, and only after long digestions. The solution is deep-yellow, and muriatic acid precipitates from it the colouring matter having a light brown colour.

When heated in the open air it behaves rather like a vegetable than an animal substance. It does not melt nor swell, gives out little smoke, but emits a disagreeable vegetable odour. When the heat is increased it burns with flame, and leaves a greyish ash having a shade of red. This ash dissolves with effervescence in nitric acid, and leaves a little peroxide of iron behind.

Gmelin distilled the pigmentum nigrum and obtained an empyreumatic oil, carbonate of ammonia, and combustible gas, and water. The charcoal remaining in the retort amounted to 44·6 per cent. of the pigmentum nigrum distilled. This charcoal was difficult to incinerate. The ashes which it left consisted of chloride of calcium, carbonate and phosphate of lime, and peroxide of iron. A solution of chlorine made the pigmentum nigrum much paler and dissolved about the half of it. The undissolved portion was rendered deep-brown, and readily dissolved by potash ley. The acids precipitated it from that solution with a brown colour. Fuming nitric acid dissolved the pigmentum nigrum with effervescence, and the solution had a reddish brown colour, was bitter, and partly precipitated yellowish brown by water and an alkali. When concentrated sulphuric acid was heated with pigmentum nigrum sulphurous acid was given out, and a black solution was formed, from which water threw down brown flocks, which were not so easily dissolved by potash as the unaltered pigment. Boiling muriatic acid dissolved a small quantity of the pigment; the solution had a brown colour. Caustic potash dissolved it slowly and incompletely at the boiling temperature; the solution had a reddish brown colour and disengaged ammonia. Muriatic acid threw down from this solution brown flocks, soluble in cold potash ley and in ammonia. The pigmentum nigrum is insoluble in both fixed and volatile oils.*

In short, the properties of the pigmentum nigrum of the eye are very similar to those of the dark matter which constitutes the ink of the cuttle-fish.

Dr Scherer subjected it to an ultimate analysis.† He obtained,

Carbon, .	58·21
Hydrogen, .	5·92
Azote, .	13·77
Oxygen, .	22·10
	100·00

* Berzelius, Traité de Chimie, vii. 451.

† Ann. der Pharm. xl. 63.

Were we to construct an empirical formula it would be $C^4 H^{29} Az^5 O^{13}$, showing that it has nothing in common with protein cuticle, horn, hair, or feathers.

CHAPTER XXIX.

OF SILK.

SILK is the production of different species of caterpillars. The *Phalena bombyx* is most commonly propagated for that purpose; but the *Phalena atlas* yields a greater quantity. A substance somewhat analogous is yielded by the greater number of the tribe of caterpillars. It is found enclosed in two small bags, from which it is protruded in fine threads, to serve the insect for a covering during its chrysalis state. The silk worm is a native of China, and feeds on the leaves of the white mulberry. That industrious nation was acquainted with the manufacture of silk from the most remote ages; but it was scarcely known in Europe before the time of Augustus. Its beauty attracted the attention of the luxurious Romans; and after the effeminate reign of Elagabulus it became a common article of dress. It was brought from China at an enormous expense, manufactured again by the Phenicians, and sold at Rome for its weight in gold. In the reign of Justinian, (from A. D. 527 to 565), this commerce was interrupted by the Scythian tribes, and all attempts to procure it failed: till two Persian monks had the address to convey some of the eggs of the insect from China to Constantinople, concealed in the hollow of a cane. They were hatched and the breed carefully propagated. This happened in the year 555 of the Christian era; and some years after, we find that the Greeks understood the art of procuring and manufacturing silk as well as the orientals. Roger, King of Sicily, brought the manufacture to that island in 1130, forcibly carrying off the weavers from Greece, and settling them in Sicily. From that island the art passed into Italy, and thence into France, and the revocation of the edict of Nantz established the manufactory of silk in Britain.

What constitutes silk exists in the body of the worm in a liquid state. In proportion as it exudes from the animal it har-

dens into a thread, and is then distinguished by the name of *raw-silk.* There is another liquid which exudes from the silk at the same time, and which, by solidifying, covers the thread with a kind of varnish. The raw-silk as spun by the worm is rather brittle. It acquires flexibility and softness by boiling it with soap and some other processes, through which it passes before it is manufactured into silk cloth or ribbons or thread.

Roard in 1807 published an elaborate set of experiments on silk.* He examined the action of water, alcohol, acids, alkalies, and soap upon silk, and extracted from it various substances, which he distinguished by the names of gum, colouring matter, and wax. His paper was valuable; but organic chemistry had not at that time made sufficient progress to enable him to make a satisfactory analysis of silk. The subject was taken up by Mulder in 1836.†

To analyze silk Mulder weighed out 77·2 grammes of raw yellow silk, and 59·55 grammes of white raw-silk. Being washed in cold water that liquid was rendered yellow by the yellow silk. It had dissolved the substance which constitutes the difference between yellow and white raw-silk. From this it would appear that this substance is soluble in cold water.

1. Both kinds of silk were now boiled in distilled water, renewed repeatedly till the water ceased to be thrown down by the infusion of nut-galls. Long boiling and much water was necessary to free the silk from every thing soluble in that liquid. By this treatment the yellow silk was rendered lighter coloured; but the white was not altered. Both had acquired a softer feel. Being dried the white silk had lost 16·75 grammes of its weight, and the yellow 22·28. Or the white silk lost 28·12, and the yellow 28·86 per cent.

The decoctions being evaporated to dry-ness over the water bath, a brittle greenish coloured matter remained, not altered by exposure to the atmosphere. This is the substance which Roard distinguished by the name of *gum.*

2. The silk was now boiled in absolute alcohol. The yellow silk lost its colour. The treatment was continued as long as the alcohol acquired any colour from the yellow silk. The alcoholic solutions from both silks were distilled till only four ounces

* Ann. de Chim. lxv. 44.

† Poggendorf's Annalen, xxxvii. 594, and xl. 266.

of each remained. On cooling both deposited bulky flocks, which were separated by the filter. The liquid being still farther concentrated deposited more flocks, which were added to the former ones. These flocks from the yellow silk amounted to 1·03 grammes, and from the white to 0·62, or 1·33 per cent. fro the yellow, and 1·04 from the white.

3. When the alcoholic tincture ceased to deposit any more flocks it was evaporated to dryness. That from the white silk gave out a peculiar smell and let fall a colouring matter, which adhered to the bottom of the vessel in stripes. The alcohol from the yellow silk deposited a similar substance of a yellow colour.

This matter from the yellow weighed 0·11 grammes, and from the white 0·15 gramme. Or that from the yellow silk was 0·14 per cent., and that from the white 0·25 per cent. The residue from the white silk had a fine red colour.

4. The silks were now digested in repeated portions of ether, till that liquid ceased to dissolve anything. The ether being evaporated, there remained a colourless residuum, weighing from the yellow silk 0·01 gramme, and from the white 0·03; or 0·012 per cent. from the yellow, and 0·05 from the white.

After these processes, the yellow and white silk could not be distinguished from each other by their appearance.

5. The silk thus treated with water, alcohol, and ether was now digested in concentrated acetic acid. There remained undissolved of the yellow silk 41·19 grammes, of the white silk 32·18; or of the yellow 53·3 per cent., and of the white 54·0 per cent.

6. The substance (No. 1,) which had been separated from the silks by boiling them in water was treated with alcohol raised to the boiling temperature. When the tinctures cooled, flocks similar to those of (No. 2) separated. While under the liquid, they were very bulky, but when the alcohol was distilled off they lost much of their bulk, and formed a clammy substance very small in quantity; since that from the yellow silk weighed only 0·05 grammes, and that from the white 0·04; or that from the yellow amounted to 0·064 per cent., and that from the white to 0·067 per cent. The residual alcohol being evaporated, left a residue too small to be weighed.

7. This clammy substance was digested in ether. But the ether being evaporated, left a residue too small to be weighed.

Mulder considers the substances thus obtained as constituting the principles of which the silk is composed.

1. The substance extracted by boiling water, and remaining after the residue of the decoction had been treated with alcohol and ether, was heavier than water, friable, and destitute of taste and smell. It did not totally dissolve in water. The solution was thick and opal, and adhered to the fingers; but it did not gelatinize on cooling. Both silks yielded to boiling water two different substances, one of which was insoluble in boiling water, and could be separated by the filter, the other forming a thick adhesive solution. The first of these substances Mulder considers as *albumen*, the second as *gelatin*.

2. The flocks which were deposited from the alcoholic solution when it cooled, he distinguishes by the name of *cerin*.

3. The substance which remains when the alcoholic solution, freed from the bulky flocks, is evaporated to dryness, consists of a fatty matter and a resinous body, and besides these two in the residue from the yellow silk, there was a quantity of colouring matter.

4. What the ether dissolved was also a mixture of fatty matter and resin.

5. The substance dissolved from the silk by concentrated acetic acid possessed the characters of that obtained by water, and which he had already distinguished by the name of *albumen*.

6. The substance remaining undissolved after the silk had been subjected to the action of all these reagents, Mulder considered as *fibrin*.

The following table shows the results obtained by these analyses:

	Yellow Silk.	White Silk.
Fibrin,	53·37	54·04
Gelatin,	20·66	19·08
Albumen,	24·43	25·47
Cerin,	1·39	1·11
Colouring matter,	0·05	0·00
Fatty matter and resin,	0·10	0·30
	100·00	100·00

1. The properties of the fibrin from silk and its constitution, according to Mulder's determination, have been given in a pre-

ceding chapter of this volume. It differs so much, both in its properties and composition from *fibrin* from blood, that it would be better to distinguish it by a particular name.

2. The substance from silk which Mulder calls gelatin is brittle, slightly yellowish, and translucent. It has neither taste nor smell, is not altered by exposure to the air, and is specifically heavier than water. When heated it swells up, catches fire, burns with flame, and leaves a bulky charcoal. When this charcoal is burnt, it leaves a white residue, consisting chiefly of carbonate of soda. In water it is completely soluble, but it is insoluble in alcohol, ether, fixed and volatile oils. The aqueous solution is very glutinous, and speedily undergoes decomposition, giving out an ammoniacal smell.

It is soluble in concentrated sulphuric acid at the common temperature of the atmosphere, without undergoing any change of colour. When heated, the solution blackens and gives out an odour of caromel and sulphurous acid. In dilute sulphuric acid, it dissolves when assisted by heat. If we boil the solution, saturate the acid with chalk, filter and evaporate and digest the residue in alcohol, that liquid, on cooling, deposites a quantity of sugar.

Concentrated nitric acid dissolves the gelatin of silk at the ordinary temperature of the atmosphere. When heat is applied, nitrous gas escapes, and oxalic acid is formed.

It dissolves in concentrated muriatic acid without change of colour. Both common and pyrophosphoric acids dissolve it. The solution in concentrated acetic acid, when evaporated, leaves a thick liquid matter, from which water precipitates nothing, but prussiate of potash throws down a beautiful green precipitate, which is soluble in water.

It is soluble in potash, soda, and ammonia, but is precipitated again by acids. If we add these alkalies to an acid solution, a precipitate falls which is redissolved if we add an excess of the alkali. It is soluble by boiling in carbonate of potash.

The aqueous solution being evaporated to the requisite consistence, becomes gelatinous and adhesive. The aqueous solution is precipitated white by alcohol, infusion of nut-galls, nitrate of mercury, diacetate of lead, chloride of tin, chlorine and bromine. The chloride of gold throws down a yellow precipitate.

It is not precipitated by oxalic acid, acetate of lead, corrosive

sublimate, nitrate of silver, nitrate of cobalt, cyanodide of mercury, chloride of iron, chloride of barium, sulphate of potash, iodide of sodium, hydriodate of ammonium, acetate of copper, tartar emetic, borax, nor persulphate of iron.

It was analyzed by Mulder, who obtained

Carbon,	47·5735
Hydrogen,	6·0660
Azote,	16.3210
Oxygen,	30·0395
	100·0000 *

To form an idea of its atomic weight, he precipitated it by diacetate of lead. The white precipitate, washed and dried at 248°, was composed of

Gelatin,	56·61 or 18·26
Oxide of lead,	43·39 or 14
	100·00

If we consider the compound as a digelate, the atom of gelatin will be 36.52. Hence he considers the constitution of the gelatin from silk to be

23 atoms carbon,	= 17·25 or per cent.	47·18
17½ atoms hydrogen,	= 2·1875 ...	5·98
3½ atoms azote,	= 6·125 ...	16·75
11 atoms oxygen,	= 11·000 ...	30·09
	36·5625	100·

If we compare these constituents with those of collin obtained from skins and isinglass, as analyzed by Mulder himself, and which have been given in a preceding chapter, it will be obvious that the constitution is not the same. But it is possible that this difference may arise at least in part from our ignorance of the true atomic weight of collin. The subject requires and deserves farther investigation.

3. The substance to which Mulder gave the name of *albumen* is friable and specifically heavier than water. On a red-hot iron it is charred with the smell of horn. It burns with flame, leaving behind it a great quantity of white ash, consisting chiefly of carbonate of soda. When distilled *per se* it gives out much car-

* Poggendorf's Annalen, xl. 288.

bonate of ammonia and an empyreumatic oil. A portion of it put into concentrated sulphuric acid remained twenty-four hours unaltered. When heated it became black, and sulphurous acid was given out. It does not dissolve in dilute sulphuric acid even though assisted by heat. Nor does nitric acid attack it at the common temperature of the atmosphere. But when the albumen is moist, concentrated nitric acid dissolves it and converts it into oxalic acid.

Muriatic acid does not attack it at the common temperature of the atmosphere; but dissolves it when assisted by heat; or when the albumen is moist. Both common and pyrophosphoric acid blacken and decompose it. When dissolved in concentrated acetic acid the albumen gives a solution having an oily appearance, which Mulder considers as a very remarkable property. Prussiate of potash throws down a beautiful green precipitate not soluble in water.

It is soluble in potash, soda, and ammonia, and is again precipitated by acids. It is insoluble in the alkaline carbonates.

Mulder subjected it to analysis and obtained,

Carbon,	54·005
Hydrogen,	7·270
Azote,	15.456
Oxygen,	23·269
	100·000*

These numbers approach those obtained by Mulder from the albumen of eggs and of blood.

4. The *cerin* was grey, specifically lighter than water, melted when gently heated, and burnt with a very light flame. It was insoluble in water, but dissolved readily in alcohol, ether, fixed and volatile oils.

Concentrated sulphuric acid decomposes it at a high temperature. Nitric acid and muriatic acid do not attack it. When boiled with caustic potash it is partly dissolved; but again separates when the solution cools. When alcohol is added it does not dissolve the matter unless heat be applied. Ether does not dissolve it. It is soluble in caustic ammonia and in concentrated acetic acid.

5. The colouring matter extracted from yellow silk was of a

* Poggendorf's Annalen, xl. 270.

fine red colour. When pure it is insoluble in water, but it dissolves in alcohol, ether, fixed and volatile oils. When treated with chlorine or sulphurous acid, it becomes of a very light yellow or almost colourless.

From the observations of Reaumur, it would appear that various colouring matters are found in silk. For he mentions white, yellow, brown, and green silk.

6. The *fatty matter* and *resin* from yellow silk are obtained mixed with the colouring matter. When the mixture of the two is exposed to a gentle heat, the fatty matter first melts, and then the resin. If we agitate the mixture with a little alcohol, and then evaporate, the resin separates in stripes, and leaves the fatty matter alone dissolved in the alcohol.

The fatty matter and resin are soluble in alcohol, ether, fixed and volatile oils, but not in water. They are specifically lighter than water, and their colour is grey.

CHAPTER XXX.

OF SPIDER'S WEBS.

THE spider, as is universally known, carries in the abdomen a peculiar liquid, which it is capable of protruding from a number (usually five) of mammillated eminences. This liquid hardens as soon as it is emitted, and adheres so firmly to everything with which it comes in contact, that it cannot be separated without rupture. This is what constitutes the web of the spider. Every thread of the web consists of several very minute threads adhering together. Spiders are oviparous, and they enclose their eggs in a cocoon of much stronger thread than that of which their webs are made. These cocoons may be winded like those of the silk-worm, and M. Bon of Montpelier first showed that spider's silk is as strong and as beautiful as that of the silk-worm. In 1710 he published the processes by which he collected this silk, wove it and dyed it of various colours; and he assures his readers that it is in no respect inferior to the silk from the silk-worm.* In consequence of the account given by M. Bon, Reaumur was

* Phil. Trans. xxvii. 2.

induced to try to breed spiders for the sake of their silk. But he found that they could not be kept together; because, being all cannibals, they devoured one another, till at last, however numerous at first, only a single spider was left alive in the box.

Spider's webs have long been a popular remedy for slight wounds; the country people being in the habit of applying them to cuts, and apparently with success, to stop the bleeding. They have been also administered internally as a cure for fever, and were at one time a popular remedy, particularly in intermittents.

From the great resemblance which the threads of the spider bear to silk, we would naturally expect their composition to be similar. But, from the experiments of M. Cadet,* the only chemist who has hitherto examined spider's webs, it does not appear that this supposed analogy holds good.

When spider's webs are triturated with quicklime, they give out a smell of ammonia. When they are digested in cold water, that liquid assumes a reddish-brown colour, and is slightly precipitated by infusion of nut-galls. It is also precipitated by acids; but the precipitate is redissolved when the acid is saturated with ammonia.

Spider's webs, cleansed as much as possible from dirt and dust, were boiled in distilled water. The decoction smelled of mushrooms, and lathered when agitated. The undissolved matter was boiled in additional water, till it gave out nothing more. These decoctions being evaporated, let fall successive pellicles, and a solid extract was at last obtained, amounting to nearly the half of the spider's webs employed.

The residue insoluble in water was digested in alcohol. The tincture obtained had an orange colour, and did not lather, water being added to it threw down a precipitate in flocks, which assumed a brown colour when dry, and amounted to about $\frac{1}{170}$th of the original weight of the webs. On hot coals it swelled up, smoaked, and took fire; and possessed properties similar to those of a resin.

The dilute alcoholic solution being evaporated, afforded a residue slightly deliquescent, having a taste at first sweetish, but afterwards bitter, and amounted to about three times the weight of the resin.

* Nicholson's Jour. xi. 290.

The insoluble residue after this treatment with water and alcohol burned without swelling up, and gave out white fumes, having the smell of burning wood. It was neither discoloured by chlorine nor by sulphurous acid. It dissolved with effervescence in muriatic acid, which took up two-thirds of it, and left a black paste. From this solution ammonia threw down a small quantity of brown matter, which, when calcined, did not lose its colour. It was chiefly oxide of iron. The liquid to which the ammonia had been added gave a gray precipitate with potash, which was chiefly carbonate of lime.

When caustic potash is poured upon the residue of spider's webs previously treated with water and alcohol, it dissolves it partially, while a little ammonia is given out. From this solution an acid throws down a black tasteless powder, which slightly swells when heated, and when dried is brittle, and has the aspect of a resin. It amounts to about one-twelfth of the exhausted spider's webs made use of. It is partly soluble in volatile oils.

The aqueous extract of spider's webs when digested in alcohol gave out about one-seventh of its weight. The alcohol, when evaporated, left a brown matter, pretty deliquescent, and having a sharp taste. It swelled considerably on burning coals, and burnt rapidly as if it had contained nitre. It contained chloride of calcium, and a sulphate probably of ammonia.

What remained of the aqueous extract after treatment with alcohol was lighter coloured than before, was in powder, and had a slightly pungent taste. On hot coals it did not swell, but left an abundant residue. Sulphuric acid poured on it occasioned no smell, nor did quicklime evolve ammonia.

When spider's webs were distilled *per se* they gave out water slightly coloured at first, but becoming darker as the process went on. Then a black thick oil came over with inflammable gas and carbonic acid. The smell of ammonia was perceptible, and the charcoal remaining amounted to about half the weight of the spider's webs employed. This coal, when incinerated, left two-thirds of its weight, half of which was soluble in muriatic acid, and the residue was silica and charcoal, the muriatic acid solution being evaporated left sulphate of lime. When spider's webs were incinerated in an open vessel, the ashes consisted of sulphate of lime, common salt, and carbonate of soda, a little oxide of iron, silica, and alumina.

Spider's webs were almost wholly soluble in six times their weight of nitric acid, carbonic acid and deutoxide of azote being disengaged. The solution gave sulphate of lime, and the *bitter* principle of Welter.

PART II.

OF THE LIQUID PARTS OF ANIMALS.

THESE consist of *blood* and of the various liquid *secretions*. They are numerous. But many of them cannot be procured in a state of purity. We shall treat of them in succession in the following chapters.

CHAPTER I.

OF BLOOD.

BLOOD is a well known fluid that circulates in the veins and arteries of man, and the more perfect animals. The quantity in a moderate-sized man is about 26 lbs. avoirdupois. Its colour is red, and it has a peculiar smell, which has been termed by physiologists *fragrant* and *alliacious*. When examined in the living animal by a microscope, it has the appearance of a greenish yellow serous liquid, in which a great number of red coloured globules are floating. When drawn out of the living body and left at rest, the globules fall to the bottom, in consequence of their greater specific gravity, and coagulate into a firm gelatinous red coagulum, called the *crassamentum* or *clot* of the blood; while the greenish yellow *serum* floats above it.

One of the first persons who attempted a chemical examination of the blood was Mr Boyle in his *Memoirs for the Natural History of Extravasated Human Blood*, published in 1684. He showed that dried human blood is very combustible, burning with a clear yellow flame. He found the specific gravity of the blood of a healthy man to be 1·118. It was coagulated by al-

cohol, nitric acid, sulphuric acid, and muriatic acid, and by a saturated solution of carbonate of potash, but rendered more liquid by ammonia. He subjected it to distillation, and obtained what he called *volatile salt of human blood,* doubtless *carbonate of ammonia.* He obtained also empyreumatic oils, and a *caput mortuum,* or fixed residue, very difficult to incinerate. He observed that the ashes left after the combustion of human blood had a brick red-colour; though he does not seem to have suspected the presence of iron in them.

Boyle attempted to determine the proportion between the serum and crassamentum of blood. But his method was so inaccurate that it is needless to state the result. He found the specific gravity of serum 1·193. The serum was coagulated by acids and by carbonate of potash; but not by ammonia. It was coagulated also by corrosive sublimate. It seems needless to state the results obtained by the distillation of serum as, from the infant state of chemistry, when these experiments were made, they could lead to no useful information.

In the year 1719, Dr Jurin made some experiments to determine the specific gravity of blood, which approached considerably nearer the truth than those previously made by Mr Boyle.* He showed by decisive experiments that the crassamentum was specifically heavier than the serum, though the contrary had been inferred from the experiments of Boyle. He found the specific gravity of human serum in seven experiments to vary from 1·0286 to 1·0302; the mean of the seven being 1·0295. The specific gravity of human blood in five trials he found to vary from 1·051 to 1·055; the mean of the five being 1·0533. Dr Jurin made some experiments to determine the specific gravity of the crassamentum, and concluded it to be about 1·126. But his method was not susceptible of accuracy.

Boerhaave's System of Chemistry, first published in 1732, contains nothing more on the chemical properties of blood than had been long before stated by Boyle.

In a note to Dr Lewis's translation of Neumann's Chemistry, published in 1759, the fibrin of blood is first mentioned, and the method of obtaining it detailed; though it is not distinguished by any name.†

Leewenhoek observed the globules of the blood as early as the

* Phil Trans. Vol. xxx. p. 1000 † Works of Casper Neumann, p. 551.

year 1674; showed that they are heavier than serum, and reckoned their diameter $\frac{1}{1940}$ of an inch.*

In the year 1747, Menghini, published a memoir in which he proved the existence of iron in the blood,† especially in the red globules. According to him, when preparations of iron are taken into the stomach, the metal speedily makes its way into the blood, when it may be detected by analysis.

Nothing or almost nothing was known respecting the saline constituents of the blood till Rouelle published his researches on the subject in the *Journal de Medecine*, for the year 1773 and 1776. He observed, that not only the serum of blood, but also the water of dropsies, is coagulated by heat and acids like the white of an egg. He found that these liquids gave a green colour to syrup of violets, and concluded that they contain a fixed alkali. This alkali in human blood is soda; though he showed by combining it with sulphuric acid and crystallizing that some potash was also present in it. Rouelle found, likewise, some common salt, animal earth,‡ and iron in the ashes of blood. The soda in blood, according to him, is to the saline contents of that liquid as 16 or 17 to 28 or 29. The animal earth constitutes about a tenth of the whole ashes of blood. The iron, he says, has a yellow colour, and in general is attracted by the magnet. Indeed it was by means of the magnet that Menghini separated it. Rouelle examined likewise the blood of the ox, the horse, the calf, the sheep, the hog, the ass, and the goat, and found in it the same salts as in human blood, though with some difference in the proportions, not only in the different animals, but even in the same species.

He made some experiments on the serum of blood, from which apparently originated the opinion long entertained, that blood contained gelatin as one of its constituents. He evaporated serum of blood to dryness over the vapour bath. It then assumed the appearance of glue, with this difference, that it was less soluble in water, and that it had the property of coagulating at the boiling temperature of water. From these properties he concluded that it possessed at once the nature of gelatin and of albumen.

* Phil. Trans. ix. 23, and xxxii. 341.

† *De ferreorum particulorum sede in sanguine.* Commentar. Bononiens., 1747, ii. 475.

‡ Afterwards shown to be phosphate of lime.

Bucquet about the year 1776 * made some interesting experiments on blood. He found that the crassamentum might, by means of water, be divided into two distinct substances; namely, the colouring matter, which was soluble in water, and which, if we except its red colour, possesses nearly the characters of the serum; and a white fibrous portion, which he distinguished by the name of the *fibrous part* of blood.† This substance coagulates when blood is allowed to cool, and then becomes insoluble in water. When dried in a very moderate heat it becomes hard and brittle, assumes a dirty grey colour, and contracts as parchment does when exposed to the same heat.

Fourcroy and Vauquelin turned their attention to animal substances at an early period of their chemical career; and in 1790 announced the discovery of *bile* and *gelatin* in ox blood. They affirm that, if the serum of blood mixed with the third of its weight of water be coagulated by heat, and the albumen separated, the residual liquid, when sufficiently concentrated, assumes the form of a jelly. ‡

Fourcroy assures us that blood coagulates when cooled down to 77°, and that in the act of coagulation the thermometer rises 11°·25, making the coagulating point 88°25.§ The serum, according to him, coagulates at 155°·75. These and many other observations on the blood, made about the same time (1790) by Fourcroy, are so inaccurate that it seems unnecessary to detail them.

Nearly about the same time a chemical examination of the blood, with observations on some of its morbid alterations, was published by Parmentier and Deyeux. ‖

In 1797, a paper was published by Dr Wells on the colouring matter of the blood.¶ In this paper he explained the reason of the change of colour which blood experiences by the action of air, and showed, contrary to the opinion at that time universally prevalent, that the colouring matter of blood is not iron, but an organized substance of an animal nature.

* See *Dictionnaire de Chimie*, par Macquer, 2d edition, article *Sang des Animaux*.

† It is the substance now called *fibrin*. This name, I presume, was contrived by Fourcroy.

‡ Ann. de Chim. vi. 181.

§ Ibid. vii. 146.

‖ Jour. de Phys. 1794, p. 372, 438.

¶ Phil. Trans. 1797, p. 416.

In 1801, the *Systeme des Connoissances Chimiques*, by Fourcroy, was published. In the ninth volume of that work there is a long account of the chemical properties of blood,* which, though it contained no new investigations, yet must have been of advantage to chemists, by exhibiting in one view all that had previously been done on the subject.

In the year 1806, Berzelius published the first volume of his Animal Chemistry. In it he gives an account of the chemical constitution of the blood, so far as it was known when he wrote, chiefly from Fourcroy; at least the statements are similar to those of that chemist, and Berzelius seems to have made no experiments. But the second volume of his Animal Chemistry appeared in 1808. To this volume he prefixed an introduction of fifty-nine pages, in which he gives a minute account of a laborious set of experiments on blood, which he had made in the interval between the publication of the two volumes. In this introduction, he gives a minute account of the chemical properties of *albumen, colouring matter,* and *fibrin,* and made the first analysis of blood. This analysis, considering the state of our chemical knowledge of the subject before it appeared, is remarkably accurate, and does great credit to the industry and sagacity of the author of it.

In the year 1812, an ingenious set of experiments on the blood and some other animal fluids was published by Mr Brande.† He showed that the red colour of the blood was not owing to phosphate of iron, as Fourcroy and Vauquelin had asserted, but to a peculiar animal matter, as had been previously maintained by Dr Wells. Mr. Brande proved also that what had previously been taken for gelatin in the serosity of the blood was in reality albumen held in solution by an excess of soda. The absence of gelatin had been previously discovered by Berzelius; but the Animal Chemistry of that chemist having been published in the Swedish language, was unknown to Mr Brande till after the publication of his memoir.

Rather before Mr Brande's paper an elaborate and remarkably exact analysis of the serum of the blood was published by Dr Marcet.‡ He turned his chief attention to the saline ingredients of blood, and his results agreed remarkably well with those of Berzelius upon the same subject.

* It occupies sixty pages of the English translation.

† Phil. Trans. 1812, p. 90.

‡ Medico-Chirurgical Transactions, ii. 370.

In the year 1831, M. Lecanu published a most elaborate memoir on the blood.* His chemical analysis of that fluid was more minute than that of Berzelius, and he detected several constituents which had escaped the sagacity of that chemist. He then made a comparative analysis of the blood of individuals of different ages, sexes, and temperaments; and he terminated his researches by an analysis of the blood of an individual labouring under jaundice, in order to determine whether the matter of bile was present in it or not. In 1837, M. Lecanu, when he received the degree of M. D. published a thesis, entitled *Etudes Chimiques sur le Sang Humain.* In this thesis he gives a detailed account of all that has been done respecting the chemical analysis of the blood either by himself, or the many chemical writers who preceded him. To this thesis I refer such readers as are interested in such historical details; and therefore terminate this historical introduction here without mentioning the names of many other individuals to whom we owe important facts respecting the blood. Many of these will be noticed in the course of the statements which will occupy this chapter.

After this historical sketch of the progress of the chemical investigation of the blood, I proceed to lay the principal facts which have been ascertained before the reader.

1. Blood is a liquid which circulates through living animals, and which is destined to nourish the different parts of the animal body, and to supply the part of the waste which is constantly going on in it. In mammalia, birds, reptiles, fishes, and annelides, it has a *red* colour; while in the crustacea, arachnides, insects, and zoophytes, it is white or colourless. Hitherto chemists have confined their examination to human blood and to the blood of certain mammalia, especially of the ox and sheep; the white or colourless blood still remains unexamined.

When blood is drawn from a vein its colour is dark, when from an artery it is scarlet. And venous blood, upon exposure to the air, speedily assumes a scarlet colour. Fresh-drawn blood has a peculiar odour, which has been compared to that of garlic, though scarcely, I think, with propriety. It has an unctuous feel and a certain viscidity, which gradually increases as the temperature sinks.

Its mean specific gravity is 1·0507. This will appear from the following little table:

* Jour. de Pharmacie, xvii. 485 and 545.

3

Sp. gr.		
1·050	By my trial.	
1·0530	Richardson.	
1·0527	Haller, Phys. ii. 41.	
1·0570	Berzelius, Chimie, vii. 31.	
1·0510	Arterial blood.	Dr J. Davy, Journal of Science, No. 4.
1·0490	Venous blood.	
1·0552	From temporal artery.	Scudamore, Essay on Blood, p. 36.
1·0532	Venous blood.	
1·0490	From jugular vein.	
1·0560	Bullock's blood.	Fourcroy, Ann. de Chim. vii. 147.
1·0310	Calf's blood.	Andrews, Records of Science, i. 33.
1·0530	Venous blood.	Do. Ibid.
1·0507	Mean.	

2. When blood is drawn from a living and healthy animal, it is in a liquid state or nearly so. But it gradually coagulates, and this coagulation takes place though the temperature of the liquid be kept up, and whether it be exposed to or screened from the action of the atmosphere. The blood of different animals, and even of the same animal, at different times, shows a considerable variation in the time that elapses after the blood is drawn before it coagulates. This will appear from the following table, for which we are indebted to Mr Thackrah:

Blood of the	coagulates in from
Horse	2 to 15 minutes.
Ox,	2 to 10
Dog,	½ to 3
Sheep, hog, rabbit,	½ to 1½
Lamb,	½ to 1
Fowls,	½ to 1½
Mice,	in a moment.
Fish,	in a moment.*

3. When blood is viewed by a microscope while circulating through the web of a frog's foot, or when newly drawn from a living animal, it is found to consist of a yellow fluid, through which a number of red globules are floating. These red globules appear to have been first noticed by Leewenhock in the year 1674,† He observed that they were heavier than the liquid in which they floated. For soon after the blood is let out of the veins, the glo-

* Hunter on the Blood, p. 211. † Phil. Trans. ix. 23.

bules gradually begin to subside to the bottom. He considered them to be 25000 times smaller than a grain of sand.* Dr Jurin afterwards pointed out a method of measuring their diameter, and concluded it to amount in the globules of human blood to $\frac{1}{1940}$ of an inch.† They have since been measured by a variety of micrometers. The following table, drawn up by Mr Lecanu, will show the result of these different measurements.*

Size of globules in human blood.

Observer	Size
Sir Everard Home,	$\frac{1}{1692}$th of an inch.
Eller,	$\frac{1}{1932}$
Jurin,	$\frac{1}{2256}$
Rudolphi, Sprengel, Nodgkin, Lister,	$\frac{1}{2800}$
Senac,	$\frac{1}{3300}$
Tabor,	$\frac{1}{3600}$
Kater,	$\frac{1}{3996}$
Prevost and Dumas,	$\frac{1}{4036}$
Haller, Wollaston, Weber,	$\frac{1}{4992}$
Young,	$\frac{1}{6062}$

It has been observed that the size of the globules differs very much in different animals. In the frog they are so large that they are capable of being retained on a filter. The liquid which passes through is yellow, while all the red colouring matter constituting the globules remains on the filter.

Various opinions have been advanced respecting the shape of these globules. I pass by the opinion of Leewenhoek, which seems whimsical. Father de Torre, who made use of very small sphericles of glass to examine them, considered them as very compressed flat spheroids, or rings having a perforation in the centre.§ Mr Hewson, whose microscopical observations on the blood were first published in the Philosophical Transactions,|| in order to observe them easily, diluted the blood with fresh serum. In man, he says, the globules of the blood are as flat as a shilling, and

* Phil. Trans. ix. p. 121. † Ibid. 1723, Vol. xxxii. p. 341.

‡ Etudes Chimiques sur le Sang Humain, p. 40.

§ Phil. Trans. 1765, p. 246. || Ibid. 773, p. 303.

appear to have a dark spot in the middle. In the frog the globules are six times as large as in man. In the blood of that animal it is easy, he says, to show that the globule is not perforated as Torre supposed; but that the dark spot is a little solid body, which is contained in the middle of a vesicle. Hence, he calls the globules *red vesicles,* each, according to him, being a flat vesicle, with a small solid sphere in its centre. When a little water is added to the blood, the vesicles swell and become round, and if the glass plate on which they are lying be placed obliquely, they may be seen running down it, while the little central solid may be seen falling from side to side like a pea in a bladder. Water gradually dissolves the red vesicles, leaving the central solid undissolved, But if a little salt be added to the water, the vesicles become flat, and do not dissolve.

Hewson conceived that the use of the thymus and lymphatic glands was to form the central solids, and that the vesicles which surround them are formed in the spleen.

But this hypothesis respecting the formation of the red globules has not been confirmed by later observers. Nor has Hewson's account of the shape and structure of these globules been admitted as exact. They seem to be flat ellipsoids, and the notion of their being vesicles containing a central nucleus has not been adopted.

In the blood of the frog, where the globules are six times as large as in human blood, the globules may be separated from the serum by the filter. In all red-blooded animals the globules may, by careful washing, be deprived of their colour. The red colouring matter dissolves in the water, but the globules remain undissolved, and assume a whitish colour.*

Lecanu has shown by experiments seemingly decisive, that the globules of blood consist at least of three distinct substances, namely, hematosin, albumen, and fibrin, and that the weight of hematosin does not exceed $\frac{1}{30}$th part of that of the globule. †
The fibrin, in his opinion, constitutes the outer surface of the globules, and envelopes a compound of hematosin and albumen, which has been generally taken for the colouring matter of blood.

* Mr Gulliver has examined and described the globules in a great number of animals. His valuable results may be seen in the Philosophical Magazine, (3d series) xvi. 23, 105, 195. They are too long and too little connected with chemistry to find a place here.

† *Etudes Chimiques sur le Sang Humain,* p. 48.

I. The number of constituents discovered in blood, not reckoning water, which constitutes a considerable portion of it, amount at least to 22. The following table exhibits the names of these substances:

1. Albumen.
2. Hematosin.
3. Yellow colouring matter.
4. Fibrin.
5. Extractive matter.
6. Serolin.
7. Cholesterin.
8. Cerebrote.
9. Iron.
10. A volatile fatty acid salt.
11. Soap of margaric and oleic acids.
12. Common salt.
13. Chloride of potassium.
14. Sal-ammoniac.
15. Sulphate of potash.
16. Carbonate of soda.*
17. Carbonate of lime.
18. Carbonate of magnesia.
19. Phosphate of soda.
20. Phosphate of lime.
21. Phosphate of magnesia.
22. Lactate of soda.

Let us take a view of these different substances in succession.

1. *Albumen.*—It has been already observed, that when healthy blood is drawn from an animal and left at rest, it gradually separates into two portions; namely, a gelatinous looking substance, containing all the red globules, and called the *crassamentum* or *clot*, and a liquid portion of a greenish yellow colour, which floats on the surface, called the serum.

It was first observed by Dr Harvey, that when the serum is heated it coagulates and becomes as firm as the white of an egg, though not so white.† The point of coagulation, as measured by my thermometer, is 159.° It had been long known that the white of an egg coagulates when heated to the same point. Rouelle and Bouquet about the year 1776, first compared serum of blood and white of egg together, and concluded that both contained a similar substance, which from the white of egg, which contains it in the state of greatest purity, has got the name of *albumen.*

The albumen of eggs was examined with some care by Neumann, who ascertained its property of being coagulated by heat, alcohol, and acids, found that in a gentle heat it might be evaporated to dryness, constituting a yellowish translucent substance resembling amber in appearance, and still capable of dissolving

* Dr Davy is of opinion that the soda in blood is in the state of sesquicarbonate. See Phil. Trans. 1838, p. 291.

† De Generatione Anim. p. 161.

in cold water. When thus dried 100 parts of albumen were reduced to 25 parts.

Albumen combines both with acids and bases. It is precipitated in grey flocks by tannin.

2. *Fibrin.*—When the crassamentum of blood is put into a linen cloth, and carefully washed till all the red colouring matter is removed, the substance which remains has received the name of *fibrin.* When moist it is white, soft, and composed of long fibres or threads. Hence the reason of the name, which seems to have been first imposed by Fourcroy and Vauquelin.

It was long the opinion of physiologists, that the globules of the blood consisted of a nucleus of fibrin inclosed in a vesicle of colouring matter. Hence was inferred the reason why it exists in the crassamentum. But later observations have considerably modified this opinion. Piorry and Scelles de Mondezert have remarked, that if we cautiously and rapidly remove the serum which floats upon the crassamentum, we will frequently find it become opaline and muddy, and finally, it is covered with a skin analogous if not identical with fibrin.* According to Muller, if we amputate the thigh of a frog, and mixing the blood with an equal quantity of water, holding sugar in solution, throw the whole upon a moistened filter, the red globules, which are very large in that animal, are retained upon the filter, while a colourless and clear liquid passes through. In this liquid a coagulum of fibrin speedily appears.

From these facts there seems no reason to doubt that the fibrin exists in the serum as well as albumen; and that the globules consist of a red colouring matter, and a white insoluble substance, the nature of which has not been ascertained; though in all probability it is analogous to coagulated albumen or fibrin. Indeed, Lecanu has shown by numerous experiments, that the globules consist essentially of three distinct substances, namely, hematosin, albumen, and fibrin.†

Fibrin may be procured likewise from the muscles of animals. Mr Hatchett cut a quantity of lean beef into small pieces, and macerated it in water for fifteen days, changing the water every day, and subjecting the beef to pressure at the same time, in order to squeeze out the water. The shreds of muscle, which amounted to about 3 lbs., were now boiled for five hours every

* Lecanu, p. 43. † Ibid. p. 50.

day for three weeks, in six quarts of fresh water, which was regularly changed every day. The fibrous part was now pressed and dried by the heat of a water bath. In this state it possessed the characters of almost pure fibrin.*

It is extremely difficult to free the fibrin of blood completely from the hematosin. The easiest way is to stir new drawn ox blood rapidly with a stick. The fibrin adheres to the stick. Let it be taken off and well-washed in cold water till that liquid ceases to be coloured. Then steep it in cold water for twenty-four hours, washing it frequently and carefully during that time. Finally, let it be digested in alcohol, or still better in ether, to separate a fatty matter which it still contains.

3. *Hematosin.*—This name was given by M. Chevreul to the colouring matter of blood, which Dr Wells, as early as 1797, showed to be an animal substance of a peculiar nature. Vauquelin and Brande proposed processes for obtaining it in an isolated state. But they did not succeed in freeing it from the albumen with which it is always mixed in the crassamentum. The processes of Berzelius and Engelhart enabled chemists to obtain hematosin in a state of tolerable purity; but, as it was coagulated and consequently insoluble in water, it was not possible to determine its characters with the requisite precision.

4. *Cholesterin.*—This is the name by which the white crystalline matter constituting the principal part of human biliary calculi has been distinguished. Its existence in the serum of blood was discovered in 1833, by M. Felix Boudet.† His discovery was confirmed by Lecanu in 1837.‡ It was extracted in the following manner: 1000 grammes of human serum were dried over the vapour bath, the dry residue was pulverized, passed through a sieve, and treated three times with ether in Chevreul's digester. The etherial liquids were mixed together, and three-fourths of them were distilled off. The residue was evaporated to dryness over the vapour bath. A considerable quantity of matter remained, which had a fatty aspect, a disagreeable smell, and the consistence of honey.

When digested in alcohol a portion was dissolved, which had a yellow colour and reacted as an acid. When left to spontaneous evaporation it deposited a pearly matter, which possessed the characters of cholesterin.

* Phil. Trans. 1800, p. 327. † Jour. de Pharm. xix. 294.

‡ Etudes Chimiques sur le Sang Humain, p. 46.

5. *Oleic and Margaric acids.*—Boudet seems first to have noticed these acids in the serum of blood, and to have extracted them in the state of a soap.* They were afterwards obtained by Lecanu. When the yellow alcoholic liquid, described in the last paragraph, from which the cholesterin has precipitated by spontaneous evaporation, is evaporated over the vapour bath, there remans a yellowish transparent matter, evidently a mixture of an oily, yellow, and colourless solid matter.

The yellow oily matter was liquid, very soluble in cold alcohol, which it rendered acid; very soluble in alkaline solutions, and not capable of being distilled over with water. It was *oleic acid.*

The colourless solid substance had a pearly lustre, was very little soluble in cold alcohol; but very soluble in cold ether. It was very soluble in boiling alcohol, which it rendered acid, and was deposited when the liquid cooled in pearl-coloured plates. It melted between 131° and 136°, and when calcined left no alkaline residue. It was margaric acid.

6. *Serolin.*—This substance was detected in the serum of blood by M. Boudet in 1833.† He obtained it by setting aside a hot alcoholic decoction of dried serum. As the alcohol cooled, a white matter, having a slightly pearly lustre, was deposited. It was the *serolin.*

7. *Cerebrote.*—This substance was first discovered in the serum of blood by Chevreul. The discovery was confirmed by the subsequent researches of Boudet. It was obtained by this last chemist in the following way:

Serum of blood, dried and deprived of every thing which boiling water is capable of extracting, was reduced to powder and treated with boiling alcohol. The alcoholic solution on cooling deposited serolin. The filtered liquid was distilled till three-fourths of the alcohol passed over. The residue became muddy, but nothing was deposited. Being cautiously evaporated to dryness, a yellowish brown matter remained, of the consistence of turpentine, which formed an emulsion with cold water. Its taste was acrid and analogous to the fatty matter of the brain. When triturated with cold alcohol of 0·8428, till nothing more would dissolve the substance that remained possessed the characters of the fatty matter of the brain.

* Journ. de Pharmacie, xix. 264. † Ibid. xix. 299.

8. *Urea.*—It has been long known that urea constitutes one of the characteristic constituents of urine. Now urine is separated from the blood by the kidneys, and it has been the general opinion of physiologists, that the constituents of urine are not merely separated from the blood by the kidneys, but that they are actually generated from the blood by these organs. But the experiments of Prevost and Dumas have demonstrated the contrary of this. It follows from their experiments that urea exists in blood ready formed; but, as the kidneys are constantly separating it from that liquid, the quantity of it, when the animal is in a state of health, is always so small that it cannot be detected in blood by the most delicate tests which we have it in our power to apply. Prevost and Dumas separated both the kidneys from dogs, cats, and rabbits, and examined the blood of these animals four or five days after the excision. They always discovered in this blood a notable quantity of urea.* As urea exists in urine combined with lactic acid, there can be little doubt that this is the case also with the urea in the blood.

9. The preceding eight substances are the only ones (the salts excepted) which have been hitherto shown to exist constantly in healthy blood. A variety of other bodies have been noticed by chemists, but they are omitted here, because their existence or their characters have not been sufficiently constated. Thus Fourcroy and Vauquelin,† Proust,‡ and Orfila,§ announced the existence of *bile* in blood. Deyeux and Parmentier stated the existence of gelatin as a constant constituent of blood.‖ Deyeux suggested the existence of a peculiar matter in the globules of blood, to which he applied the name of *tomellin,* and to which he ascribed the homogeneous concretion of the entire blood in the preparation of puddings.¶ Denis makes *osmazome* one of the constituents of blood.** All these and several other substances noticed by Lecanu, as *cruorin, erythrogen,* have been omitted, because their existence in blood has not been demonstrated, nor have their properties been sufficiently determined.

10. *Soda.*—The serum of blood renders cudbear paper purple, and therefore contains an alkali. This alkali in human blood is

* Ann. de Chim. et de Phys. xxiii. 90.
† Ibid. vi. 181, vii. 154.
‡ Ann. de Chim. xxxvi. 276.
§ Elemens de Chimie, ii. 313.
‖ Jour. de Phys. xliv. 438.
¶ Syst. de Conn. Chim. ix. 210. English translation.
** Recherch. Experim. sur le Sang Hum. p. 107.

soda. Whether it be the same alkali that exists free in the serum of the blood of the inferior animals, or whether potash may not replace it at least in some, has not yet been determined. Most chemists affirm that the soda in human blood is in the state of carbonate. But I have not been able to satisfy myself that this is the case. It is more probable that at least a portion of it is united to lactic acid. It has been satisfactorily proved that albumen is capable of combining with alkaline bodies, and that this combination increases its solubility. It is most reasonable to admit that the soda in human blood, not in combination with acids, is united to the albumen, and that to this combination the solubility of the albumen in the serum is at least partly owing.

11. It has been already stated that the first person who turned his attention to the salts in blood was Rouelle. He detected common salt, phosphate of lime, and some potash, as well as soda.

Dr Marcet made a careful analysis of the serum of blood about the year 1812, and extracted from 1000 parts of that liquid,

Chlorides of potassium and sodium, .	6·60
Carbonate of soda, . . .	1·65
Sulphate of potash, . . .	0·35
Phosphate of lime with trace of magnesia,	0·60
	9·20
Mucous extractive matter, . .	4·0
Albumen, ...	86·8
Water, ...	900·0
	1000·0*

Berzelius had analyzed the serum of blood in 1808,† though his results were not known in this country till he came to London in 1812. He obtained from 1000 parts of serum of human blood,

Common salt, . . .	6	
Lactate of soda, . . .	4	
Soda, phosphate of soda with some albumen,	4.1	
		14·1
Albumen, ...		80
Water, ...		905·9
		1000.

* Medico-Chirurgical Transactions, ii. 370. † Djurkemien, ii. 55.

The mucoso-extractive matter of Marcet, and the lactate of soda of Berzelius, are two different names given to the same substance.

The crassamentum yielded when incinerated an ash, which, when 1000 parts were burnt, amounted to 15. Of this ash, water dissolved three parts, consisting partly of carbonate of soda, and partly of phosphate of soda. The undissolved portion consisted of,

Peroxide of iron,	5
Perphosphate of iron,	1
Bonearth,	1
Pure lime,	2
Carbonic acid,	1
	10

The following table exhibits the salts which exist in human blood, according to the latest statements of Lecanu; though he has nowhere, so far as I have observed, given a detail of the method by which they were detected.

1. Common salt.
2. Chloride of potassium.
3. Sal-ammoniac.
4. Sulphate of potash.
5. Carbonate of soda.
6. Carbonate of lime.
7. Carbonate of magnesia.
8. Phosphate of soda.
9. Phosphate of lime.
10. Phosphate of magnesia.
11. Lactate of soda.
12. Margarate and oleate of soda.
13. A volatile fatty acid salt.

12. Having now stated the different substances which exist in blood, with the exception of the gaseous bodies which have been detected by various chemists, it may be proper, before proceeding farther, to notice these gases as shortly as possible. The gases found in blood are oxygen, azotic and carbonic acid.

It was long ago shown by Hoffmann and Steevens that, when venous blood is kept in the vacuum of an air-pump, carbonic acid gas is given out. But, as succeeding experimenters did not succeed on their trials, it was long generally admitted that venous blood contained no sensible quantity of carbonic acid gas, and hence it was inferred that the carbonic acid gas in expired air was formed in the lungs. The experiments of Magnus have at last proved in the clearest manner that blood, both venous and arterial, contains carbonic acid, oxygen, and azotic gases. *

* Ann. de Chim. et de Phys. lxv. 169.

When a current of hydrogen gas, azotic gas, or even oxygen gas is passed through venous blood, it gives out carbonic acid to the amount at least of one-fifth of the volume of the blood. When venous or arterial blood is kept in the vacuum of an air-pump, it gives out gaseous matter, which was collected and analyzed by Magnus. The following table shows the results obtained:—

	Volume.	Vol. of gases.	Composition.
Arterial blood of a horse,	125	9·8	5·4 carbonic acid.
			1·9 oxygen gas.
			2·5 azotic gas.
Venous blood of ditto, four days after the arterial,	205	12·2	8·8 carbonic acid.
			2·3 oxygen.
			1·1 azote.
Same blood,	195	14·2	10·0 carbonic acid.
			2·5 oxygen.
			1·7 azote.
Arterial blood of an old horse,	130	16·3	10·7 carbonic acid.
			4·1 oxygen.
			1·5 azote.
Same blood,	122	10·2	7·0 carbonic acid.
			2·2 oxygen.
			1·0 azote.
Venous blood of same horse three days after,	170	18·9	12·4 carbonic acid.
			2·5 oxygen.
			4·0 azote.
Arterial blood of a calf,	123	14·5	9·4 carbonic acid.
			3·5 oxygen.
			1·6 azote.
Same blood,	108	12·6	7·0 carbonic acid.
			3·0 oxygen.
			2·6 azote.
Venous blood of ditto, four days after,	153	13·3	10·2 carbonic acid.
			1·8 oxygen.
			1·3 azote.
Same blood,	140	7·7	6·1 carbonic acid.
			1·0 oxygen.
			0·6 azote.

Dr Davy has found that fresh blood, when agitated with oxygen gas or common air, absorbs a little oxygen gas, while the thermometer rises one or two degrees, without giving out any carbonic acid gas. He could not find that blood gave out carbonic acid gas when agitated with other gases; but it absorbed more than its own volume of carbonic acid. *

It is not easy to draw any inference from these contradictory experiments.

II. Proportion of the constituents of Blood.

Having described the different substances which enter into the constitution of blood, let us now endeavour to state the varying proportions of each in different circumstances.

1. When blood is left at rest it divides into two portions, the serum and crassamentum. The proportion between these two differs greatly under different circumstances.

(1.) There is a considerable diversity in the specific gravity of serum as will appear from the following table:

Sp. gravity.	
1·027 to 1·029	Berzelius.
1·085	Marcet, Med.-Chir. Trans. iii. 363.
1·0287	By my trials.
1·0262	Richardson.
1·0264 Arterial.	Dict. de Sciences Natur. Sang. p. 181.
1·0257 Venous.	
1·047 to 1·050	Dr Davy, Phil. Trans. 1814, p. 591.
1·020 of a calf after three bleedings.	Andrews, Records of Science, i. 53.
1·017 do. after four bleedings.	

If we leave out the determinations of Dr Andrews, because the blood was not in a normal state, the mean specific gravity of serum is 1·0296. And if we leave out the determination of Dr Davy, which deviates too far from the rest, the mean specific gravity of serum will be 1·0265.

(2.) The mean specific gravity of the crassamentum, according to Dr Jurin, is 1·245.†

(3.) The crassamentum cannot be freed completely from the serum. It consists essentially of the globules of the blood; and these globules, according to the experiments of Lecanu, are composed of fibrin, hematosin, and albumen.

(4.) The following table exhibits the proportions between the

* Phil. Trans. 1834, p. 283. † Haller's Physiology, ii. 41.

water, salts, &c., albumen of serum and globules in the blood of individuals of different ages. The table was drawn up by Lecanu from his own experiments.*

Water.	Salts, &c.	Albumen of Serum.	Globules.	Age of the Individual.
780·210	14·000	72·970	132·820	45
790·900	8·870	71·560	128·670	26
782·271	10·349	66·090	141·290	36
783·890	9·770	67·890	148·450	38
805·263	12·120	65·123	117·484	48
801·871	11·100	65·389	121·640	62
785·881	10·200	64·790	139·129	32
778·625	11·541	62·949	146·885	26
788·323	8·928	71·081	131·688	30
795·870	10·010	78·120	115·850	34
805·263	14·000	78·120	148·450	Maximum.
778·625	8·870	67·890	115·850	Minimum.
26·638	5·130	10·230	32·600	Difference.
789·3204	10·6888	68.059	132·4906	Mean of 10 analyses.

(5.) The preceding table will give the reader an idea of the various proportions between the serum and crassamentum of blood in different individuals. Let us now see what is the constitution of the serum according to the various analyses that have been made.

Dr Marcet found the constituents of serum as follows:

Water,		900
Albumen,		86·8
Chlorides of potassium and sodium,	6·60	13·2
Mucous extractive matter,	4·00	
Carbonate of soda,	1·65	
Sulphate of potash,	0·35	
Earthy phosphates,	0·60	
		1000

Berzelius obtained,

Water,		905
Albumen,		80
Alkaline chlorides,	6	14
Lactate of soda, &c.	4	
Carbonate of soda, Phosphate of soda, Animal matter,	4	
		999

* Etudes Chimiques sur le Sang Humain, p. 62.

Prevost and Dumas obtained,

Water,	900
Albumen and salts,	100
	1000

Lassaigne obtained,

Water,	910
Albumen and salts,	90
	1000

Lecanu obtained,

	1st Analysis.	2d Analysis.
Water,	906·	901·
Albumen,	78·	81·2
Extractive,	3·79	4·60
Fatty bodies,	2·20	3·40
Alkaline chlorides,	6·00	5·52
Alkaline carbonate, phosphate, and sulphate,	2·10	2·00
Carbonates of lime and magnesia, Phosphates of lime and magnesia.	0·91	0·87
	998·90	998·59

M. Lecanu made other experiments. He dried a given weight of serum, digested it in alcohol and water, and ascertained by evaporation the weight of the substances extracted by these vehicles. His results were as follows:

Water,	909·330	Maximum,	920·546
		Minimum,	900
Albumen,	78·013	Maximum,	88·520
		Minimum,	67·980
Extractive salts, Fatty matters,	12·656	Maximum,	17·000
		Minimum,	10·160

(6.) The crassamentum cannot perhaps be completely freed from serum; but, by washing the globules in a saturated solution of sulphate of soda, they may be made tolerably pure. In that case we estimate the constitution of the globules according to the determination of Lecanu as follows:

Fibrin, .	2·253
Hematosin, .	1·735
Albumen, .	96·012
	100·

The following table exhibits the constituents of human blood as determined by Mr Richardson in my laboratory. His colouring matter was obviously the globules of the blood, consisting of fibrin, hematosin, and albumen, in the proportions just stated:

Specific gravity of the blood, 1·053.

Water, ...	785·890
Fibrin, . . .	2·120
Colouring matter, . . .	134·780
Albumen, . . .	63·008
Cholesterin and serolin, . .	1·357
Oily fatty matter, . .	0·808
Extract and lactic acid, . .	1·831
Albuminate of soda, . .	0·956
Alkaline chlorides, . . .	5·341
Alkaline carbonate, sulphate, and phosphate,	2·110
Subsesquiphosphate of iron, . .	1·021
Subsesquiphosphate of lime, . .	0·056
Phosphate of magnesia, . .	0·193
Peroxide of iron, . .	0·203
Carbonate of lime, Carbonate of magnesia, } . .	0·326
	100·000

The following curious table, drawn up by M. Denis from his own experiments, and exhibiting the constitution of blood at different ages, deserves to be inserted.*

	Water.	Fibrin.	Albumen.	Globules.	Salts, &c.	Total.
At birth, .	86	0·9	8·1	3·4	1·6	100
From birth to 10,	82·5	1·5	7·7	6·8	1·5	100
10 to 20,	79	1·4	6	12·1	1·5	100
20 to 30,	76	1·0	5·7	15·7	1·6	100
30 to 40,	76	1·2	6	15·2	1·6	100
40 to 50,	76	1·2	6·7	14·6	1·5	100
50 to 60,	78	1·2	7	12·5	1·3	100
60 to 70,	79·5	0·9	7	11·3	1·5	100

* Jour. de Physiol. ix. 218.

Many experiments have been made to determine whether any difference exists between the blood of males and females. From the trials of Lecanu it follows that the proportion of albumen in both is sensibly the same.

		In man.	In woman.
Maximum,	.	78·270	74·740
Minimum	.	57·890	59·159
Mean,	.	68·080	66·9495

The proportion of globules is greater in the blood of men than in that of women.

		In man.	In woman.
Maximum,	.	148·450	129·999
Minimum,	.	115·850	68·349
Mean,	.	132·150	99·1695

The proportion of water is greater in the blood of women than of men.

		In man.	In woman.
Maximum,	.	805.263	853·135
Minimum,	.	778.625	790·394
Mean,	.	791·944	821·7645

With respect to temperament, the blood contains more water in persons of a lymphatic than of a sanguine temperament; the proportion of albumen is nearly the same in both, but the globules are more numerous in the blood of sanguine than of lymphatic individuals.

When blood is repeatedly drawn from the same individual the proportion of water increases, while that of the globules diminishes after each bleeding. This was ascertained by M. Lecanu* and by Dr Andrews.†

In the case of uterine hemorrhagy the proportion of water is greatly augmented, while that of the globules, and even of the albumen is much diminished.‡ When the nourishment is diminished, the water in the blood increases, while the globules diminish. The albumen is not much altered in quantity.

Many experiments have been made to ascertain whether any difference exists between venous and arterial blood. The following table exhibits the specific gravity of each as determined by different experimenters:

* Jour. de Pharmacie, xvii. 557.

† Records of General Science, i. 31.

‡ Lecanu, Jour. de Pharmacie. Ibid.

Arterial.	Venous.	
1·049	1·051	John Davy on calves, oxen, sheep, dogs.
1·053	1·058	Scudamore. Human blood.
1·0433	1·0487	Letellier. Human blood.
1·0398	1·0429	
1·0455	1·0531	
1·0461	1·0507	Mean.

Arterial blood coagulates and putrefies more rapidly than venous blood.

The crassamentum from arterial blood is more bulky and firm than that from venous blood. The amount of the difference will be seen in the following table:

	Crassamentum.	Serum.
In the cat,	1163	8837 in venous blood.
	1184	8816 in arterial.
In a sheep,	861	9131 in venous.
	935	9065 in arterial.
In a dog,	970	9300 in venous.
	995	9005 in arterial.

From the experiments of Prevost and Dumas, it appears that the proportion of fixed matters to water is greater in arterial than in venous blood. This will be seen by the following table:

	Arterial blood.		Venous blood.	
	Fixed matters.	Water.	Fixed bodies.	Water.
In the sheep,	17·07	82·93	16·36	83·04
In the cat,	17·65	82·35	17·41	82·59
In the cat,	19·62	79·38	19·08	80·92
Mean,	18·11	81·89	17·62	82·38

The analyses of Lecanu agree with those of Prevost and Dumas; but Denis made four analyses of the arterial and venous blood of a man, of a woman, and of a dog, and found the proportions of water and fixed matters the very same, both in venous and arterial blood.

The albumen, salts, and fatty matters, as far as can be inferred from a considerable number of comparative experiments, exist in the very same proportions in arterial and venous blood.

Many other comparative experiments on arterial and venous

blood have been made. But the results obtained are so inconsistent with each other that no satisfactory conclusions can be deduced from them. The following may be considered as the differences between arterial and venous blood, which seem to be pretty satisfactorily determined.

1. The colour of arterial blood is scarlet, that of venous brownish red and much darker.

2. Arterial blood coagulates more rapidly than venous blood.

3. The crassamentum from arterial blood is more bulky and firmer than that from venous blood.

4. Arterial blood contains less water than venous blood.

5. Arterial blood contains more globules and more fibrin than venous blood.

6. The albumen, fatty matters, and salts, are the same in both.

7. Probably arterial blood contains most oxygen gas, and venous blood most carbonic acid gas.

8. According to the analysis of MM. Macaire and Marcet Junior, arterial blood contains more oxygen than venous blood, while venous blood contains more carbon than arterial blood. The result of their analyses was as follows:*

	Arterial.	Venous.
Carbon,	50·2	55·7
Hydrogen,	6·6	6·4
Azote,	16·2	16·2
Oxygen,	36·3	21·7
	99·3	100·0

9. The specific gravity of arterial blood is rather higher than that of venous blood.

Would it be safe to infer from these facts, that the part of the blood chiefly employed in nourishing the living body is the globules, and that the diminution of these globules during the circulation is made up again while the blood is passing through the lungs? The chyle contains globules; but they are white, and it appears from the analyses of Macaire and Marcet that the quantity of azote is much greater in blood than in chyle.

Dr Denis made a comparative analysis of the blood drawn from a vein and from the capillary vessels by means of cupping-glasses. But no appreciable difference could be discovered.

* Mem de la Societé Phys. et d'Hist. Nat de Genev. v. 223.

Prevost and Dumas analyzed the blood of the vena portæ, and obtained the following results.*

Water,	.	801·4
Albumen and salts,		84·4
Globules,	.	114·2
		1000·0

The globules, as might be expected, are less and the water more than in venous blood; doubtless because a considerable portion of the globules in the arterial blood has been employed in nourishing the abdominal viscera from which the *vena portæ* proceeds.

According to Denis, the blood of the placenta contains less water and more globules than the venous blood of the same woman. The albumen, fatty matters, and salts are sensibly the same. This blood has the smell of the liquor of the amnios, and a decidedly brownish red colour. The blood of the fœtus is quite similar to that of the placenta. It contains less water and more globules than that of the same child some time after birth. The placenta supplies the place of breathing to the child. We see that, like the lungs, it furnishes the blood with an additional quantity of globules.

VENOUS BLOOD DURING VARIOUS DISEASES.

The colour of venous blood varies in different diseases. In inflammatory fever it is more scarlet, or approaches somewhat to that of arterial blood. In Asiatic cholera, scurvy, and typhus, it has a deep-red colour approaching to black.

The specific gravity increases in inflammatory diseases and in certain phlegmasiæ, also in the common cholera, and in certain dropsies. It diminishes in scurvy, putrid disease, different cachexiæ, such as diabetes, scrofula, chlorosis, copious hæmorrhagies, typhus and malignant exanthemata.

The smell changes completely in scurvy, confluent small-pox, and putrid fevers.

When healthy blood is drawn from a vein it always, after a certain interval of time, separates into serum and crassamentum. In disease it sometimes coagulates more rapidly than in

* Ann. de Chim. et de Phys. xxiii. 57.

health; sometimes more slowly, and sometimes so imperfectly that the clot bears a stronger resemblance to *sanies* than to the crassamentum of healthy blood. It coagulates more rapidly in inflammatory diseases, and in cases of plethora; more slowly in putrid fevers, scurvy, and other cachexiæ.

The crassamentum is bulky and consistent in plethoric and inflammatory diseases; but small, soft, and diffluent in scurvy and typhus. In very malignant diseases, as the yellow fever, it lets fall a black pulverulent sediment.

After great hæmorrhagies, in asthenic diseases, and in affections of the heart, the serum is very abundant compared with the crassamentum. Its colour is deep-yellow in jaundice, lemon-yellow in inflammatory diseases, muddy, and whitish in puerperal fever.

Sometimes a kind of crust covers the crassamentum, usually distinguished from its colour by the name of the *buffy coat.* This is the case in inflammatory diseases, in intermittent fevers, and in the yellow fever. This crust seems to be fibrin, and its position is probably owing to the globules being deposited more rapidly than in healthy blood.

MM. Andral and Gaverrey have examined the blood in 360 cases of patients in the Hospital de Charité in Paris.* They have drawn from this examination the following general results:

1. In acute inflammation, as rheumatism, pneumonia, bronchitis, pleurisy, peritonitis, amygdalites, erysipelas, and pulmonary tubercles, the fibrin of the blood increases.

2. In pyrexia, both typhoid and non-typhoid, eruptive fevers, as small-pox, measles, scarlatina, and in intermittent fevers, the globules increase while the fibrin remains normal or diminishes.

3. In chlorosis the globules diminish.

4. In the malady of Bright the albumen diminishes.

Let us now endeavour to point out the alterations which the blood undergoes in certain diseases. On this subject a great many important facts have been collected by M. Lecanu.† It will be sufficient here if we lay before the reader an abstract of his researches.

1. *Blood of infants attacked with induration of the cellular tis-*

* Ann. de Chim. et de Phys. lxxv. 225.

† Etudes Chimiques sur le Sang Hum. p. 94.

sue.—Blood obtained by incisions into the skin of children who died of this disease contained, according to Chevreul, water, globules, and a fibrinous matter, possessed of little tenacity. The serum separated from the crassamentum was almost colourless. In a few minutes it assumed the form of a jelly, owing probably to some change in the state of the albumen.

2. *Menstrual Blood.*—This blood is a mixture of arterial blood and mucous matter, varying in proportion according to circumstances. That of a woman, 27 years of age, analyzed by Dr Dennis, contained,

Water,	825·0
Globules,	64·4
Albumen,	48·3
Extractive matter,	1·1
Fatty matters,	3·9
Salts,	12·0
Mucus,	45·3
	1000·0

It has usually a dark-red colour, a peculiar smell, and, instead of crassamentum, contains small clots of little consistency.

Dr Rainy, Professor of Forensic Medicine in the University of Glasgow, analyzed a quantity of menstrual blood, obtained by puncturing an imperforated hymen. It was above six weeks old, but not much putrid. It was quite fluid, and could easily be poured and even dropt from a phial. It was browner in the colour than ordinary blood, somewhat fœtid, and disengaged ammonia on the addition of potash. When examined under the microscope, the globules were seen apparently as numerous as in ordinary blood; but their shape was somewhat irregular, as is usually the case with putrid blood. It was composed of

Water,	88·55
Solid residue,	11·45
	100·00

Mr Macconechy found the serum of this blood composed of

Water,	91·28
Solid residue,	8·72
	100·00

From this analysis Dr Rainy concludes that the blood consisted of

Serum, .	97·22
Globules, .	2·78
	100·

Dr Rainy could detect no fibrin in this menstrual blood.

Mr Macconechy analyzed the serum of this blood, and obtained,

Water, . .	91·28
Albumen, . .	7·70
Common salt, . .	0·60
Soda, ...	0·02
Animal matter, Earthy phosphates,	0·40
	100·00

3. *Blood of a patient labouring under Hæmaturia.*—The remarkable circumstance in the blood in this disease is the total absence of colouring matter, as may be seen by the action of acids on healthy blood, and the blood in a case of hæmaturia.

Coagulum by	In Healthy Blood.	In Hæmaturia Blood.
Sulphuric acid	Blackish red	Blackish brown
Nitric acid	Blackish red	White
Muriatic acid	Red	White *

4. *Blood in Scurvy.*—According to Fourcroy, blood drawn from the gums of a person labouring under scurvy contains no fibrin, does not coagulate, and becomes black on cooling. According to Deyeux and Parmentier, the blood of persons ill of scurvy has a peculiar smell. The crassamentum from the blood of three different scurvy patients was as firm, and contained as much fibrin, as that of healthy blood. But the serum was difficultly coagulable by heat. One of the three crassamenta was covered with the buffy coat. These facts are of little value, having been determined at a time (1793) when the chemical investigation of animal substances had made too little progress to expect accurate experimenting.

5. *Blood in Diabetes.*—The opinion advanced by Dr Rollo, that the blood in diabetes contains sugar, has not been verified by future experimenters. Since neither Nicolas and Gueudville;

* Delarive, as quoted by Lecanu.

Vauquelin and Segelas, Wollaston and Marcet, who examined diabetes blood in succession, were able to detect any. I think it probable that it exists, but in so small quantity as not to be recognizable; being constantly removed as fast as formed by the action of the kidneys. Just as urea cannot be discovered in healthy blood, though the experiments of Prevost and Dumas show clearly that it must exist in that liquid. Henry and Soubeiran analyzed the blood of a diabetes patient in 1826, and obtained,*

Globules,	.	122·80
Albumen,	.	55·48
Salts,	.	5·57
Water,	.	816·15
		1000·00

The proportion of globules rather less than in healthy blood. This confirms the previous statement of Nicolas and Gueudville, that the globules diminish as the disease advances.

Dr G. O. Rees has also analyzed the serum of blood drawn from a diabetes patient, and obtained

Water,	908·50
Albumen, (containing oxide of iron and phosphate of lime,)	80·35
Fatty matters,	0·95
Diabetes sugar,	1·80
Animal extract soluble in alcohol and urea,	2·20
Albuminate of soda,	0·80
Alkaline chloride with trace of phosphate, Alkaline carbonate, trace of sulphate,	4·40
Loss,	1·00
	1000·00†

Dr Rees is the only chemist who has succeeded in finding sugar in the serum of diabetes blood, and his method of proceeding is not satisfactory.

6. *Blood in Jaundice.*—Many experiments have been made to determine whether bile exists in the blood of patients labouring under jaundice. But the question seems still undecided. The reason probably is that we are not in possession of any very delicate test of choleic acid. To decide the point, the best way would be to mix a quantity of fresh bile with new-drawn blood, and to make a comparative set of experiments on this mixture

* Jour. de Pharmacie, xii. 320.

† Phil. Mag. (3d series), xiii. 395.

and pure blood. Probably some differences would present themselves, which might lead to important conclusions respecting icteric blood. MM. Orfila and Clarion are of opinion that bile exists in icteric patients; Thenard and Lassaigne that such blood contains no traces of bile; while Chevreul, Boudet, Collard de Martigny, and Lecanu believe that icteric blood contains the colouring matter of bile, but none of its other constituents.

Chevreul found in the blood of icteric children three colouring matters, one orange-red, another green, and a third blue; which he considers as identical with the colouring matters in human bile. Collard de Martigny found in the blood of an icteric woman, besides the usual constituents,

1. A yellow matter, characterized by its solidity, its colour, its insipidity, want of odour, and insolubility in water and alcohol. It is almost insoluble in muriatic acid, which gradually gives it a green colour. It is very soluble in potash, from which it is precipitated by the acids. It is very little soluble in nitric acid, but assumes from it a green colour.

2. A green matter, which is soft and elastic, of a deep-green colour, without smell, acrid, soluble in potash, to which it communicates a brown colour.

It appears from the analysis of Lecanu, that the blood of persons afflicted with jaundice contains fewer globules than healthy blood. He obtained in two different trials,

Water,	828·66	830
Albumen,	76·82	65
Salts, &c.	14·90	8
Globules,	79·62	97
	1000·00	1000

The mean quantity of globules in 1000 of healthy blood is 132·49, and the minimum quantity 115·85.

7. *Blood in Asiatic Cholera.*—The blood in this disease has a much greater consistency than healthy blood. It contains a much greater quantity of fixed matter, and much less water than healthy blood. This will appear from the four following experiments of Lecanu:

	1st.	2d.	3d.	4th.
Fixed matters,	340	251	520	330
Water,	660	749	480	670
	1000	1000	1000	1000

The quantity of alkalis is greatly diminished, and it is remarkable that the excrement and matter vomited by cholera patients contain alkali. The fibrin is diminished, but the globules are very much increased in quantity.

Wittstock and Herrman could detect no urea in cholera blood, but Marchand and Dr Nagel detected it in the blood of a cholera patient who had passed no urine for three days.*

8. *Blood in Yellow Fever.*—According to Steevens the blood in yellow fever is very thick, has a very dark colour, and contains less than the usual quantity of salts. This exactly corresponds with the state of the blood in Asiatic cholera.

9. *Blood in Typhus Fever.*—The small bulk of the crassamentum, and its want of consistency in the blood of typhus patients, has been long remarked. This would indicate a diminution in the quantity of globules—an opinion confirmed by the two following analyses of M. Lecanu:

Water,	805·2	795·88
Globules,	115·0	105·00
Albumen, &c.	79·8	99·12
	1000·0	1000·00

10. Mr Gulliver has detected pus in the blood in almost every instance in which there was either extensive suppuration or great inflammatory swelling without a visible deposition of pus in any of the textures of the body. He considers the presence of pus in the blood to be the proximate cause of sympathetic inflammatory, sympathetic typhoid, and hectic fevers.†

11. *Blood in diseases of the Heart.*—M. Lecanu made several analyses of the blood of patients affected with diseases of the heart. The following table shows the results of these analyses:

	Water.	Albumen, salts, &c.	Globules.	Total.
1st male patient,	821·02	77·59	101·39	1000·00
2d male patient,	880·48	77·62	41·90	1000·00
3d male patient,	807·27	96·35	96·38	1000·00
1st female patient,	873·45	86·10	40·45	1000·00
2d female patient,	868·62	79·89	51·49	1000·00
3d female patient,	866·61	80·69	43·70	1000·00
4th female patient,	877·51	77·00	45·49	1000·00
5th female patient,	845·14	85·80	69·06	1000·00

* Poggendorf's Annalen, xliv. 328. † Phil. Mag. (3d Series), xiii. 193.

We see a great diminution in the globules and a proportional increase in the water, albumen, and salts.

12. *Blood in Chlorosis.*—In this disease there appears to be a great diminution in the globules of the blood, as appears from the following analysis of the blood of a chlorotic patient by M. Lecanu:

Water, . .	862·40
Globules, .	55.15
Albumen, &c.	82·45
	1000·00

A second analysis of the blood of the same patient made some months later gave,

Water, .	861·97
Globules, .	51·29
Albumen, &c.	86·74
	1000·00

Fœdisch made two comparative analyses of healthy blood and chlorotic blood. The result is as follows:

	Cruor.	Serum.	Fibrin.	Water.	Iron.
Healthy blood, .	124·00	86·01	25·11	756·87	8·01
Healthy blood, .	144·00	89·20	25·01	732·73	9·01
Chlorotic blood, .	91·41	93·61	6·40	826·28	3·30
Chlorotic blood, .	85·90	92·21	6·31	830·75	5·01

It was in consequence of the supposed diminution of iron which was believed to be the colouring matter of blood that physicians prescribed iron as a remedy in chlorosis.

13. *Milky Blood.*—In certain pathological states of the body not yet well determined, the blood has such a resemblance to milk that it has been compared to milk mixed with a little blood. This was for a long time ascribed to the mixture of milk with the blood. But analysis has shown that this blood does not contain the constituents of milk; but that its milky appearance is owing to the existence of fatty matters held in suspension in it. The following analysis of such a blood by Lecanu shows this very clearly:

Water,	794
Albumen,	64
Acid soap, Cholesterin (1·08), Olein, Margarin, Stearin,	117
Salts, &c.	25
Hematosin, trace.	
	1000

The analysis of Dr Christison of Edinburgh agrees with that of Lecanu.

14. *Injection of salts into the blood of living animals.*—Mr Blake has made a set of curious experiments on the action of salts when thus injected.* He finds that salts with the same base have generally the same action. The salts of magnesia when introduced in any quantity arrest altogether the action of the heart, and produce a complete prostration of muscular power. The salts of zinc are similar, but not so powerful. The salts of barytes, strontian, and lead, occasion contractions in the muscular tissues, which continue many minutes after death. The salts of silver and soda produce a remarkable action on the pulmonary tissue, which seems to occasion the death of the animal.

The preceding account applies almost exclusively to human blood. Few experiments have been made on the blood of the inferior animals. There cannot, however, be a doubt that the blood of every species of animal has something peculiar, and adapted for the animal in whose blood-vessels it flows. This is evident from the facts observed when blood is transfused from one animal to another. It is well known that when a blood-vessel in a living animal is opened, and the blood allowlowed to flow out, the animal loses all sense and motion, and speedily dies. But if the blood of another animal of the same species be made to flow into the vessels of the exhausted animal, it speedily recovers its sensibility and power of motion, and sustains no perceptible injury. The blood of a sheep in this way may be transfused without injury into another sheep. But if we transfuse the blood of a sheep into a cat or a dog, the animal dies. This must be owing either to a diversity of the proportion of the

* Phil. Mag. (3d series), xviii. 547.

constituents of the blood in different animals, or to a diversity in the constituents themselves. The few analyses of the blood of inferior animals are not capable of enabling us to decide this point; but it may be worth while to state here the principal facts which have been ascertained.

1. *Ox blood.*—Lecanu analyzed the hematosin in ox blood and obtained,

Carbon,	66·49	65·91
Hydrogen,	5.30	5·37
Azote,	10·54	10·54
Oxygen,	11·01	11.75
Iron,	6·66	6·58
	100·00	100·15

Two analyses of dried ox blood were made in Liebig's laboratory by Messrs Playfair and Böckmann. They obtained,

	Playfair.	Bockmann.
Carbon,	51·950	51·965
Hydrogen,	7.165	7·330
Azote,	17·172	17·173
Oxygen,	19·295	91·115
Ashes,	4·418	4·413
	100·000	99·996

2. *Horse's blood.*—The following table shows the difference in the proportion of water and solid matter in the arterial and venous blood of the horse :

I.—Arterial Blood.

	Water.	Solid matter.
From the aorta,	783·83	216.17
From the carotid,	785·50	214·50

II.—Venous Blood.

Water	Solid matter.
795·67	204·32
804·55	195·45

According to Magnus 1000 volumes of horse's blood gave

47 volumes of carbonic acid,
12 volumes of oxygen,
7 volumes of azote,

while 1000 volumes of calf's blood gave

4

55·6 volumes of carbonic acid,
9·6 volumes of oxygen,
6·4 volumes of azote.

3. *Blood of birds.*—Prevost and Dumas found the blood from the jugular vein of the following birds composed of,

	Clot.	Serum.	Water.
A young raven,	14·66	5·64	79·70
A heron,	13·26	5·92	80·82
A duck,	15·01	8·47	76·52
A hen,	15·71	6·30	77·99
A pigeon.	15·57	4·69	79·74

The facts just stated, few and imperfect as they are, show clearly that the constitution of the blood is different in different animals.

CHAPTER II.

OF SALIVA.

The *saliva* is a liquid secreted by six glands, three on each side of the mouth. These are the two parotids, the two submaxillary, and the two sublingual.

It is a liquid, which is colourless or nearly so. It is not quite transparent, containing a few white flocks, which gradually sink to the bottom, when the saliva is collected in a glass. Probably these flocks come from the mucus which lines the *ductus stenonianus* and the other salivary ducts.

It is not easy to form a notion of the quantity of saliva secreted by the salivary glands; though it must be considerable. M. C. G. Mitcherlich collected all the saliva from one of the parotid glands of a patient in an hospital in Berlin, who had a fistula in that parotid. In 24 hours it amounted to 1048 grains. Hence in this case the two parotids must have secreted 2096 grains in 24 hours. The submaxillary and sublingual glands are much smaller than the parotids. But if we suppose them equal to one parotid, the whole saliva secreted in 24 hours will be 3144 grains, or almost 7½ ounces avoirdupois.*

* Poggendorf's Annalen, xxvii. 320.

Most persons swallow their spittle once every two minutes. The average weight of the saliva taken into the stomach each time is 6·7 grains. This (in 16 hours) would amount to 3216 grains, or 7⅝ ounces. This estimate, (allowing eight hours for sleep, during which little saliva is secreted,) comes very near the estimate of Mitcherlich.

Haller informs us that 120 lbs. of saliva were emitted during the treatment of a syphilitic patient: but he does not say how long the treatment continued.*

Saliva in the mouth varies somewhat in its nature. Most commonly it is very slightly acid, though sometimes it is neutral, and sometimes alkaline. The saliva collected by Mitcherlich from the fistula during meals was acid; but at other times alkaline. During meals it was secreted so abundantly that it could be collected in drops. At other times the flow was much smaller.

Tiedemann and Gmelin assure us that, when pure, saliva is always alkaline; and the same statement has been made by Dr Donné.† M. Boudet has shown that the saliva and the mucus secreted in the mouth are always alkaline; but that the secretion from the gums is always acid.‡

The specific gravity of saliva varies somewhat, as may be seen from the following table:

I found it in a case of salivation,	1·0038
Tiedemann and Gmelin found it,	1·0043
Mitcherlich, from .	1·0061 to 1·0088
About dinner, Mitcherlich found it,	1·0074
Mean gravity, . .	1·00518

It has been already observed, that saliva contains white flocks, which gradually subside to the bottom. Mitcherlich found that 29·797 of saliva deposited 0·0015 of these white flocks. According to this estimate, 100000 parts of saliva contain nearly five parts of white flocks. In another experiment the quantity was greater. Berzelius estimated the quantity much higher, rather more than $\frac{1}{1000}$th of the whole. Part of this difference probably arises from the different temperatures at which the flocks were dried.

These white flocks are insoluble in water, alcohol, and acids. They are soluble in potash, and the solution is precipitated by acid. When the flocks are dried they assume a brown colour.

* Elem. Phys. lib. xviii. † Jour. de Pharm. (3d series,) i. 395.
‡ Ibid. p. 396.

Saliva freed from these flocks is quite transparent, often colourless, but sometimes it acquires a yellowish hue. At least a phial of saliva which I have kept for 25 years has assumed a rather deep brownish yellow colour, but still retains its transparency.

Alcohol added to saliva occasions a white precipitate. On heating the liquid this precipitate is partly redissolved; but it falls down again when the liquid cools.

Nitrate of silver throws down a precipitate easily soluble in ammonia.

Tincture of nut-galls throws down a light brown precipitate, soluble by heat, but again appearing when the liquid cools.

Acetate of lead throws down a copious white precipitate, not soluble by heat, but disappearing on the addition of acetic acid.

Sulphuric acid gives a slight flocky precipitate.

Caustic potash or ammonia produces no sensible effect.

Treviranus first observed that saliva got a red colour when a little perchloride of iron was mixed with it. Tiedemann and Gmelin have inferred that this colour is produced by a minute quantity of sulphocyanic acid contained in saliva. With me the experiment does not succeed; but I have been told by Dr Alexander Stewart, that the saliva of smokers was found to strike a red with perchloride of iron. Would it not seem from this as if the sulphocyanic acid in saliva were generated by the action of tobacco smoke?

Such are the effects of reagents upon saliva. Let us now see what are its constituents.

Mitcherlich evaporated 66.775* parts of saliva, of specific gravity 1·0083, to dryness in vacuo over sulphuric acid. The residue weighed 1·08 parts, or 1·617 per cent. It was divided by means of water and alcohol into the four following portions:

1. Insoluble in water and in alcohol of 0.863,	0·281
2. Soluble in water, but not in alcohol of 0·863,	0·352
3. Soluble in water, but not in alcohol of 0·800,	0·296
4. Soluble in water, and in alcohol of 0·800,	0·192
	1·121
Excess,	041
	1·080

* The quantity was 66·775 grammes, or almost exactly 1030 grains.

The following are the characters of these four divisions:

1. The substance already mentioned as existing in saliva in white flocks, and considered as mucus. It amounted in this case to 0·42 per cent. of the saliva.

Acetic acid causes it to swell up and to become gelatinous. But no solution takes place even at a boiling temperature. Sulphuric acid gives it a red colour, but produces no further alteration. Muriatic acid dissolves it, and the colour of the solution is bluish. This colour is produced slowly when the acid is cold; but more rapidly at a boiling temperature. Ammonia behaves like acetic acid. Caustic potash causes a slight swelling, scarcely perceptible, but does not dissolve it.

2. The substance soluble in water, but insoluble in alcohol of 0·863, and amounting to 0·527 per cent., is what chemists have denominated *salivin* or *ptyalin*. Its characters were first described by Berzelius.* It was afterwards examined by Leopold Gmelin. The characters given by these two chemists differ in consequence of the different methods employed to obtain the salivin. For heat alters its properties. Its characters have been detailed in the first part of this volume, while treating of *animal substances*.

3. The matter soluble in water, but insoluble in alcohol of 0·800, consists chiefly of the salts contained in saliva; but is not quite free from animal matter. It amounts to 0·443 per cent. of the saliva. It has a yellow colour and does not deliquesce. Its solution is not altered by chloride of barium, sulphuric or muriatic acid, corrosive sublimate, chloride of iron, nor by infusion of nut-galls. Acetate of lead gives a white precipitate, not redissolved by acetic acid or water. Nitrate of silver throws down a white precipitate soluble in ammonia. When burnt it gives out the smell of animal matter, and leaves a coal containing potash and soda. Probably the animal matter which it contains is salivin.

4. The matter soluble in water and in alcohol of 0·800, amounted to 0·287 per cent. It had a yellowish red colour, and deliquesced rapidly if the alkali had not been neutralized. It gave, when burnt, the same products as the other substances, and left a potash and soda salt.

The properties of this substance are best observed when the saliva has been previously neutralized by sulphuric acid. If we

* Annals of Philosophy, (1st series,) ii. 380.

expose the substance (No. 4) to the air after such neutralization it absorbs moisture; the animal matter is dissolved, while the salts remain in crystals. The liquid being poured off is found to contain no sulphuric acid. The animal matter thus separated from the salts has a red colour and an acid reaction. With acids, potash, ammonia, and corrosive sublimate, it gives no precipitate. Acetate of lead throws down a slight precipitate again redissolved by boiling. Perchloride of iron gives a flocky red precipitate not again dissolved by water. Nitrate of silver gives a precipitate soluble in ammonia.

When sulphuric acid is added to saliva to neutralize the soda which it contains, white flocks precipitate. These flocks constitute salivary mucus. As they continue to fall till the soda is saturated, and as no effervescence is perceptible, the probability is, that the soda in saliva is in combination with this mucus. The following table exhibits the saline contents of 100 parts of saliva as determined by Mitcherlich:*

Chloride of potassium, .	0·180
Potash combined with lactic acid,	0·094
Soda combined with lactic acid,	0·024
Soda combined with mucus, .	0·164
Phosphate of lime, . .	0·017
Silica, ...	0·015
	0·494

Or nearly half-a per cent.

Berzelius made an analysis of saliva, probably about the year 1810;† though we did not become acquainted with his results in this country till about the year 1813.‡ According to him 100 parts of saliva consist of

Water, ...	992·9
Salivin, ...	2·9
Mucus, ...	1·4
Alkaline chlorides, . .	1·7
Lactate of soda with animal matter,	0·9
Soda, ...	0·9
	1000·7

* Poggendorf's Annalen, xxvii. 337.

† No such analysis is to be found in the 2d volume of his Djurkemien, published in 1808.

‡ Annals of Philosophy, ii. 380.

Tiedemann and Gmelin made a great many experiments on human saliva, and on the saliva of the dog and the sheep.* They found the specific gravity of saliva made to flow by the stimulus of tobacco smoke to be 1·0043 at 53½°. It reacted feebly as an alkali, and never was acid. The residue when evaporated to dryness amounted to 1·19 or 1·14 per cent. This residue being incinerated, left 0·25 of ashes, of which 0·203 were soluble, and 0·047 insoluble in water consisting of earthy phosphates.

100 parts of the residue obtained by evaporating saliva to dryness being analyzed, yielded the following products :

1. Fatty matter, analogous to cerebrote, substances soluble in alcohol and water, extract of meat, chloride of potassium, lactate of potash, sulphocyanate of potash, . .	31·25
2. Animal substance precipitated by cooling from the solution of boiling alcohol with sulphate of potash and some chloride of potassium, . .	1·25
3. Matters soluble in water only, viz. salivin, much phosphate, and a little of sulphate of an alkali, and chloride of potassium, . . .	20·00
4. Substances neither soluble in water nor alcohol, viz. mucus, a little albumen, with alkaline carbonate and phosphate, . . .	40·00
	92·5

The 8·5 per cent. deficient was probably owing to the residue of soda still retaining water.

It may be worth while to notice the differences in the characters of salivin, as stated by Berzelius and Tiedemann and Gmelin. Berzelius found it white, Tiedemann and Gmelin light yellowish-brown.

Berzelius states it as soluble in water; Tiedemann and Gmelin found that every time it was dissolved in water it left a light-brown membranous residue.

According to Berzelius, it is not precipitated by infusion of nut-galls, diacetate of lead, nor corrosive sublimate. According to Tiedemann and Gmelin, it is precipitated not only by infusion of nut-galls, but also by lime-water, solutions of alum, and by neutral salts of copper, lead, and iron.

It is pretty clear that the salivin of Tiedemann and Gmelin was mixed with the mucus of the saliva.

* Tiedemann and Gmelin sur la Digestion, i. 4.

1. The saliva of the horse was examined by Lassaigne in 1821.* It was colourless, had a slight smell, and on exposure to the air become muddy, and let fall a white precipitate consisting of carbonate of lime mixed with a little phosphate. It was slightly alkaline, and when heated, let fall some flocks of albumen. Being evaporated to dryness, it left 3½ per cent. of matter consisting of

1. Animal matter soluble in alcohol.
2. Animal mater soluble in water.
3. Albumen.
4. Trace of mucus.
5. Chlorides of potassium and sodium.
6. Soda.
7. Carbonate of lime.
8. Phosphate of lime.

2. The saliva of the dog was pale yellow, mucilaginous, and slightly muddy; when evaporated, it left 2·58 per cent. of residue. From this residue alcohol extracted common salt, with a very little lactate of soda, and a mere trace of extract of meat. The portion insoluble in alcohol consisted chiefly of salivin united to soda. It possessed exactly the characters of salivin from human saliva.

3. The saliva of the sheep was very liquid, and not mucilaginous. Its taste was feebly saline, and its reaction was alkaline. It left a residue, when evaporated to dryness, amounting to 1·68 per cent. of the saliva. This residue was a thick white membrane which attracted some moisture when exposed to the air. Alcohol extracted from it common salt, and was reddened by perchloride of iron, indicating the presence of sulphocyanic acid. The residue left by the alcohol yielded to water a mere trace of salivin, but several saline substances. The insoluble residue was brittle and membranous. It did not dissolve nor gelatinize in acetic acid. 100 parts of this saliva contained,

1. Water, . . .	98·90
2. Matters soluble in alcohol, viz. much extract of meat, a substance which caused common salt to crystallize in octahedrons, common salt, and a little sulphocyanate of soda, ...	0·11
3. Matters soluble only in water, viz. traces of salivin, much phosphate of soda, much chloride of potassium and carbonate of soda, . .	0·82

* Ann. de Chim. et de Phys. xix. 176.

4. Matters insoluble in water and alcohol, viz mucus or coagulated albumen, a little phosphate and carbonate of lime. . . . . 0·05

99·88

It would appear from an observation of Leuchs that, when starch is boiled with saliva, the solution becomes more liquid, and acquires a sweet taste.* From this it would seem that saliva is capable of converting starch into sugar. He found that neither albumen, gelatin, nor salivin possessed this property.

The saliva is sometimes liable to undergo morbid alterations. There are two cases on record in which it contained a good deal of oxalic acid. Clerc mentions that he has sometimes observed the saliva in diseased persons acid and sometimes alkaline; but he does not seem to have made any observations to determine the nature of the acid or alkali present. It varies much in quantity and consistence: but no accurate set of observations has yet been made upon the alterations induced in saliva during various diseases. According to Dr Donné, the saliva becomes acid when inflammatory diseases of the stomach exist, and it assumes its natural state of alkalinity as soon as that inflammatory affection ceases.†

Depositions from the saliva are frequently observed on the teeth. Such depositions are known by the name of *tartar*. It is a yellowish white bony-looking concretion, which gradually accumulates on the teeth unless they be regularly cleaned. At first it is little else than the mucus of the salivary ducts, which gradually adheres to the teeth and becomes discoloured. But by degrees subsesquiphosphate of lime appears, augments the deposit, and renders it harder.

Tartar, according to the analysis of Berzelius,‡ is composed of,

Earthy phosphates,	79·0
Mucus,	12·5
Salivin,	1·0
Animal matter soluble in muriatic acid,	7·5
	100·0

* Poggendorf's Annalen. xxii. 623.

† Ann. de Chim. et de Phys. lvii. 414.

‡ Annals of Philosophy, ii. 381.

The result of my analysis of a specimen of tartar, for which I was indebted to Alexander Nasmyth, Esq., Dentist in Lon don is as follows:

Subsesquiphosphate of lime, . .	65·61
Carbonate of lime, .	7·18
Silica with trace of iron and perhaps magnesia,	1·32
Fixed alkaline chlorides, .	1·43
Mucus and albumen, . .	10·49
Salivin, . . .	1·32
Animal matter soluble in muriatic acid, .	6·02
Water, ...	6·63
	100·00

The earthy salts were obtained by digesting the tartar in very dilute muriatic acid. The acid being drawn off, was neutralized and then mixed with caustic ammonia, which threw down the calcareous phosphate. Oxalate of ammonia threw down the lime left in solution. The residual liquid being evaporated to dryness and ignited, a chloride of potassium and sodium remained, which, being dissolved, left a few black flocks, which, by digestion in nitric acid, became brown, and before the blowpipe exhibited the characters of silica tinged with iron. The bead with carbonate of soda was opal. Hence I suspected the presence of magnesia.

The water was determined by heating a portion of the tartar over the steam-bath till it ceased to lose weight. The tartar being digested in water a portion was dissolved. The water being evaporated, the residue was white; but became yellow when heated, and ceased to be quite soluble. Hence (abstracting the chlorides present) it was considered as salivin. The animal matter remaining after the tartar had been treated with muriatic acid, water and alcohol was considered as mucus. I think it probable that the animal matter dissolved in muriatic acid was salivin; but I did not succeed in getting it unaltered from that solution, and could not therefore examine its properties.

CHAPTER III.

OF THE LIQUID OF RANULA.

THE term *ranula* is applied by French medical men to a soft whitish oblong indolent tumour, situated under the tongue, near the anterior ligament. This tumour is occasioned by the retention and accumulation of the saliva in the excretory ducts of the maxillary and sometimes of the sublingual glands. As this liquid consists of altered saliva, it will be proper to give an account of it here. The only modern chemist who has examined this liquid is M. Leopold Gmelin of Heidelberg.* It was extracted from a tumour of ten years standing. The liquid was thick and adhesive like white of egg. It had a yellow colour, was muddy, and reddened litmus-paper.

A portion of it was mixed with four times its bulk of water. At first it did not seem soluble, but by long agitation it dissolved with the exception of a few very fine flocks. They were separated by the filter, but were so few that they could not be perceived when the filter was dried. The colourless solution frothed strongly when agitated, was still gelatinous, and when mixed with muriatic acid, gave, after some time, a copious white precipitate. With nitric acid it gave a yellow precipitate. With alcohol, thick white flocks, and with tincture of nut-galls, cheesy brown-yellow flocks. By potash it was not altered.

The greatest part of the liquid, amounting to 4·132 grammes, was evaporated to dryness over the water-bath. By the action of a boiling temperature it was white, almost opaque and cohered into one mass. It weighed 0·223 gramme, or 5·4 per cent. It was softened by water and then washed on the filter.

The aqueous liquid when evaporated left a minute quantity of brownish yellow residue, which was deliquescent. It was treated with alcohol, which dissolved a trace of yellowish-brown deliquescent abstract. Its solution in water gave, with acetate of lead, white flocks, and with tincture of nut-galls, brown flocks, and with nitrate of silver, a caseous precipitate. Perchloride of iron gave a deep reddish-yellow colour, destroyed by dilute muriatic acid. Hence it did not proceed from sulphocyanic acid.

* Ann. der Pharm. xxxi. 95.

This extract contained osmazome, common salt, and acetate of potash.

The portion of the watery extract insoluble in alcohol was merely a trace. It probably consisted of carbonate and phosphate of potash, and a small quantity of salivin.

The matter which had been treated with cold water was boiled in alcohol. The alcohol when evaporated left a substance like tallow, whose alcoholic solution did not redden tincture of litmus.

The portion insoluble in alcohol, which constituted the principal part of the liquid of ranula, possessed the characters of coagulated albumen.

It appears from this analysis, imperfect as it is, that the liquid of ranula has no resemblance to saliva; being destitute of sulphocyanic acid, and almost so of salivin, while it contains abundance of albumen, which is not found in saliva.

CHAPTER IV.

OF THE GASTRIC JUICE.

The change which the food undergoes in the stomach was ascribed at first to the mechanical action of the stomach, but this opinion was gradually abandoned, and chemical physiologists were almost unanimous in assigning *fermentation* as the agent, though what was meant by fermentation is far from clear. The numerous experiments of Reaumur, Stevens, and Spallanzani, demonstrated that the change of food in the stomach was owing to its solution in a liquid. This liquid was admitted to be secreted in the stomach, and was therefore called *gastric juice* (*succus gastricus.*) It seems needless to relate the attempts to collect this liquid by Spallanzani, Gosse, Brugnatelli, Carminati, &c. because they were unsuccessful. The first important step to determine its nature was by Dr Beaumont of the United States army. He has published a very interesting set of experiments on the human gastric juice,* which tend to throw a great deal of

* The original work, entitled " Experiments and Observations on the Gastric Juice and the Physiology of Digestion," was published in America in 1833. A new edition, edited by Dr Combe, appeared in Edinburgh in 1838.

new light on the process of digestion. Alexis St Martin, who was the subject of these experiments, was a Canadian of French descent. He had been engaged in the service of the American Fur Company, and was accidentally wounded by the discharge of a musket on the 6th of June 1822. The charge, consisting of powder and duck shot, was received on the left side, distant not more than a yard from the muzzle of the gun. The contents entered posteriorly, and in an oblique direction, forward and inward, blowing off integuments and muscles of the size of a man's hand, fracturing and carrying away the anterior half of the sixth rib, fracturing the fifth, lacerating the lower portion of the left lobe of the lungs and the diaphragm, and perforating the stomach. He came under the surgical treatment of Dr Beaumont, fevered, and for some time all the food taken into the stomach made its way through the perforation. Gradually, however, this was prevented by compresses applied to the opening into the stomach. By degrees the injured parts sloughed off, and the protruded portions of the stomach adhering to the *pleura costalis* and the external wound, a free exit was afforded to the contents of that organ, and effusion into the abdominal cavity was thereby prevented. In about a year and a half after the accident, the whole was healed, and the health and strength of St Martin completely restored, but the perforation of the stomach still continued. It was situated at the left and upper side of the great curvature. The external opening was about two inches below the left nipple, on a line drawn from the nipple to the left ileum.

At the point where the lacerated edges of the muscular coat of the stomach and the intercostal muscles met and united with the *cutis vera*, the cuticle of the external surface and the mucous membrane of the stomach approached each other very nearly. They did not unite like those of the lips, nose, &c. but left an intermediate marginal space of appreciable breadth, completely surrounding the aperture. This space was about a line wide; and the cutis and nervous papillæ were unprotected, and as sensible and irritable as a blistered surface abraded of the cuticle.

At first, when the stomach was empty, a portion of the mucous coat was protruded by the orifice to the size of a hen's egg, but there was no difficulty in reducing it by gentle pressure with the finger or a sponge wet with cold water, neither of which produced the least pain.

The perforation was about two inches and a half in circumference; and at first the food and drink constantly exuded unless prevented by a tent, compress, and bandage. During the winter of 1823–4, a small fold or doubling of the coats of the stomach appeared, forming at the superior margin of the orifice, slightly protruding and increasing till it filled the aperture, so as to supersede the necessity of the compress and bandage for retaining the contents of the stomach. This valvular formation adapted itself to the accidental orifice so as completely to prevent the efflux of the gastric contents when the stomach was full, but it was easily depressed by the finger, so as to give free access to the cavity of the stomach, and allow the introduction and removal of any substances, the digestibility of which was an object of experiment.

Dr Beaumont had ample opportunity of viewing the appearance of the inside of the stomach, as Alexis St Martin was his servant for several years, and was subjected by him to various courses of experiment, in order to determine the phenomena that attend the conversion of food into chyme in the stomach.

The inner coat of the stomach in its natural and healthy state is of a light or pale pink colour, varying in its hues according to its full or empty state. It has a soft and velvety appearance, and is covered with a very thin transparent viscid mucus lining the whole interior of the organ.

Immediately beneath the mucous covering, and apparently incorporated with the villous membrane, appear small, spheroidal, or oval-shaped globules, from which the mucous matter appears to be secreted.

When food or other irritants are applied to the innermost coat of the stomach, innumerable minute lucid points and very fine papillæ can be seen (by means of a magnifying glass), arising from the villous membrane, and protruding through the mucus, from which distils a pure, limpid, colourless, slightly viscid fluid, which constitutes the true gastric juice.

This liquid is invariably *acid*, while the mucous matter which covers the inside of the stomach has no taste whatever. The gastric juice thus discharged is absorbed by the aliment in contact with it, or collects in small drops and trickles down the sides of the stomach to the more dependent parts, and there mingles with the food, or whatever else may be contained in the gastric

cavity. It is never accumulated in the cavity of the fasting stomach, and is seldom or never discharged, except when the vessels secreting it are excited by the natural stimulus of food, by mechanical irritation of tubes, or by other excitements. When food is received, the juice is given out in exact proportion to its acquirements for solution, except when more food has been taken than is necessary for the wants of the system.

Probably the secretion from mechanical irritation is less than that produced by the stimulus of food: the latter is diffused over the whole villous coat, while the former is only partial. On viewing the interior of the stomach, the peculiar formation of its inner coats is distinctly seen. When empty, the rugæ appear irregularly folded on each other, almost quiescent, of a pale pink colour, and lubricated with mucus. On the application of food, the action of the vessels is increased, the colour brightened, and the vermicular motion excited. The small gastric papillæ begin to discharge a clear transparent fluid, which continues to accumulate abundantly as the food is received for digestion.

If the mucous covering of the villous coat be wiped off with a sponge during the period of chymification, the membrane appears roughish, at first of a deep pink colour, but in a few seconds the follicles and fine papillæ begin to pour out their respective fluids, which, being diffused over the parts abraded of mucus, restore to them their peculiar soft and velvety appearance and pale pink colour; and the gastric juice increases and trickles again down the sides of the stomach.

If the mucus be wiped off when the stomach is empty, a similar roughness and deep colour appear, though less in degree, and the mucus is more slowly restored. The follicles swell more gradually, and the fluids do not appear in such quantities as to trickle down, the mucus alone being restored.

In disease, the inner membrane of the stomach presents various and essentially different appearances. In fever, obstructed perspiration, undue excitement by spirituous liquors, or when overloaded with food, while under the influence of fear, anger, or whatever depresses or disturbs the nervous system—the villous coat becomes sometimes red and dry, at other times pale and moist, and loses its smooth and healthy appearance. The secretions become vitiated, greatly diminished, or entirely suppressed. The mucous covering can scarce be observed; the follicles are

flat and flaccid, with secretions insufficient to protect the vascular and nervous papillæ from irritation.

Sometimes eruptions or deep-red pimples appear on the internal coat of the stomach, not numerous, but distributed here and there upon the villous membrane. They are at first sharp-pointed and red, but frequently become filled with white purulent matter. At other times irregular, circumscribed red patches, varying from half an inch to an inch and a half in circumference, appear on the internal coat, seemingly the effect of congestion in the minute blood-vessels of the stomach. At times, small aphthous crusts in connection with these red patches are seen. Abrasion of the mucus leaving the papillæ bare for an indefinite space, is not an uncommon appearance.

When these diseased appearances are considerable, and particularly when there are corresponding symptoms of disease, as dryness of the mouth, thirst, accelerated pulse, no gastric juice can be extracted, not even on the application of the stimulus of food. Drinks received into the stomach are immediately absorbed, none remaining in that organ ten minutes after being swallowed. Food taken during this condition of the stomach remains undigested for forty-eight hours or more, increasing the derangement of the whole alimentary canal, and aggravating the general symptoms of disease.

After excessive eating and drinking chymification is retarded, and, although the appetite is not always impaired at first, the fluids become acrid and sharp, excoriating the edges of the aperture, and almost invariably producing aphthous patches, and the other indications of a diseased state of the innermost membrane, which have been already mentioned. Vitiated bile is also found in the stomach under these circumstances, and flocculi of mucus are also much more abundant than in health.

Whenever the morbid condition of the stomach appears, there is generally a corresponding appearance of the tongue. When a healthy state of the stomach is restored, the tongue invariably becomes clean.*

Dr Beaumont had an opportunity also of observing the peristaltic motion of the stomach during digestion. It causes the food

* See Beaumont's *Experiments*, Chapter vii. The above description of the appearances of the stomach in health and disease has been given as nearly as possible in the words of Dr Beaumont.

to revolve round the stomach in from one to three minutes. The consequence of this is a thorough mixture of all the different articles of food with each other. If a mouthful of some tenacious food be swallowed after digestion is considerably advanced, it will be seen passing the opening to the great curvature, and in the course of one and a half or two minutes, it will reappear with the general circulating contents, more or less broken to pieces or divided into smaller pieces, and it very soon ceases to be distinguishable.

As the food becomes more and more changed from its crude state to that of chyme, the acidity of the gastric juice is considerably increased—more so in vegetable than in animal diet—and the general contractile force of the muscles of the stomach is augmented in every direction, giving the contained fluids an impulse towards the pylorus. During the whole process of digestion, the bulk of the food in the stomach is continually diminishing; slowly at first, but more rapidly towards the conclusion of the chymification. Hence it must be passing through the pylorus during the whole time of digestion.

The gastric juice was extracted from the stomach of Alexis St Martin in the following way: He was placed on his right side. The valve within the aperture was depressed, and a caoutchouc tube of the size of a large quill was introduced five or six inches into the stomach. He was then turned on his left side so as to make the orifice dependent. The stomach was empty and contracted on itself. The tube acted as a stimulant, and the gastric juice began to flow first by drops, and then in an uninterrupted, and sometimes in a continuous stream. Moving the tube up and down, or backwards and forwards, increased the discharge. The quantity of fluid obtained was from half-an ounce to two ounces troy, according to circumstances. Its extraction was attended by that peculiar sensation at the pit of the stomach, called *sinking*, with some degree of faintness, which rendered it necessary to stop the operation. The *juice* was usually extracted early in the morning when the stomach was empty and clean. The following is a description of the gastric juice thus extracted, as drawn up by Dr Silliman, Professor of Chemistry in Yale-College.

" The fluid, after having been kept in a closely-corked phial more than three months, from April to August, and most of the

time in a cellar, remained unaltered, except the formation of a pellicle on the surface, slightly discoloured by red spots. A second pellicle appeared after the precipitation of the first. It was thicker and more discoloured with dark-red spots, like venous blood.

"The fluid was cloudy, like a solution of gum-arabic; but when filtered, it became perfectly clear, and of a slight straw-yellow tinge.

"The pellicles, which had the appearance of inspissated mucus, after being separated from the fluid, became, after exposure to the air, throughout of a brownish red colour, resembling the inner portion of a mass of coagulated blood. This change seems to result from a sudden exudation.

"The fluid exhaled a slight odour, not disagreeable—rather aromatic, and very similar to that which it at first exhaled, but not so strong. It was then rather disagreeable.

"Taste feebly saline, not disagreeable.

"Test papers of litmus, alkaline, and purple cabbage were decidedly reddened. Turmeric paper underwent no change, but when previously browned by ammonia, the gastric juice restored the yellow colour.

"Nitrate of silver gave a dense white precipitate, which, after standing five minutes in the sun's light, turned to a dark brownish-black, thus indicating muriatic acid. Muriate and nitrate of barytes gave a slight opalescence, indicating a trace of sulphuric acid. Probably there was also some phosphoric acid.

"Specific gravity about 1·005."

It was subjected to an imperfect chemical examination by Professor Dunglison and Professor Emmit of Virginia College. They found it to contain free muriatic and acetic acids, phosphates and muriates, with bases of potash, soda, magnesia, and lime, and an animal matter soluble in cold water, but insoluble in hot.

It was shown many years ago by Spallanzani, and his experiments were confirmed by those previously made by Dr Stevens, that the gastric juice acts as a solvent to the food, and that it is capable of dissolving the food out of the stomach, in phials, provided the temperature be kept as high as 100°, which is about that of the human stomach during digestion. These conclusions have been fully confirmed by Dr Beaumont, who not only witnessed the solution of almost every kind of food in the stomach

during chymification, but tried the effect of the gastric juice upon the same kinds of food in phials at the temperature of 100°, and found it to dissolve them precisely as happened in the stomach, though in general after a longer interval of time.

Dr Beaumont has published the different series of experiments which he made by introducing various articles of food into the stomach, and noticing the time that elapsed before they were digested. These experiments throw considerable light upon the relative digestibility of different kinds of food, and on that account are highly deserving the attention of medical practitioners; but, as they do not throw much light on the nature of the gastric juice, it would be improper to give an account of them here.

From the preceding account it will be seen, that there is a liquid secreted in the stomach during digestion, which has the property of dissolving the food, and reducing it to a kind of pap, in which the various articles of food are so much altered in their appearance that they can no longer be recognized by their sensible properties. We know that during mastication a considerable quantity of saliva is mixed with the food in the mouth, and passes along with it into the stomach, so that the gastric juice consists at least in part of saliva. Dr Prout has shown that the gastric juice always contains free muriatic acid, and Tiedemann and Gmelin that in animals which live on vegetables there is always free acetic acid, and occasionally free butyric acid in the stomach. Now it comes to be a question whether the saliva and these acids be not capable of converting all kinds of food into chyme, and therefore do not constitute the whole essential portion of the gastric juice. The experiments of Eberle, Müller, and Schwan have shown that something more is necessary. The following is an epitomé of their very curious experiments.

1. There are certain articles of food that are dissolved in glass tubes by saliva kept at the temperature of 100°. This is the case with boiled starch, which, by digestion in saliva, is converted into starch-gum and sugar.

2. There are certain other articles of food which are dissolved in glass tubes filled with water, acidulated with muriatic or acetic acid, and kept at the temperature of 100°. This is the case with casein, gelatin, and gluten. At least the effects of the dilute acids on these substances agree with what Tiedemann and Gmelin observed in natural digestion. Gelatin, for example, loses

its property of gelatinizing and of being precipitated by chlorine.

3. But there are various articles of food which require another digesting principle to convert them into chyme. This is the case with coagulated albumen, fibrin, and (to a certain extent also) casein. To make an artificial gastric juice, capable of dissolving these substances, a portion of the third or fourth stomach of an ox was digested for twenty-four hours in water containing $2\frac{3}{4}$ per cent. of muriatic acid, and the liquor was then filtered. It contained in solution 2·75 per cent. of solid matter, and required rather more than 2 per cent. of carbonate of potash to neutralize it. When this liquid was digested for several hours on coagulated albumen in powder, it dissolved.

Müller's experiments showed that the mere acid solution will not dissolve albumen. And Eberle and Schwann found that the same acid solution, after the third or fourth stomach of the ox is digested in it, acquires the property of dissolving albumen. It is clear from this, that something is taking up from these stomachs, which gives the acid liquor the power of dissolving albumen and fibrin. To this substance, in consequence of its digesting property, Schwann has given the name of *pepsin.**

The gastric juice, it would appear from these experiments, consists of *saliva*, of *muriatic* and *acetic acids*, and of *pepsin*. This last substance is obtained by digesting the third or fourth stomach of the ox in a dilute solution of muriatic acid. Some experiments were made by Schwann to determine the nature of pepsin. But they were not very successful. The facts ascertained have been stated in a preceding chapter, when treating of pepsin.

The most characteristic action of pepsin is its precipitating casein or coagulating milk. When 0·42 of pepsin solution is mixed with 100 of milk, the milk is coagulated. The quantity of the muriatic acid of commerce necessary to produce the same effect is 3·3 per cent.

The neutralized solution of pepsin still coagulates milk. But if its temperature be raised to the boiling point its property of coagulating milk is destroyed.

The small quantity of pepsin which causes the solution of albumen is remarkable. Acidulated water holding in solution

* From πέψις, *digestion*.

only $\frac{1}{100}$th of its weight of pepsin shows a decided action on albumen. 98 grains of water acidulated with muriatic acid, and containing only 4·8 grains of the solution of pepsin, dissolve 49 grains of albumen in twenty-four hours, when kept at the temperature of 99°.5. Now, as 4·8 grains of digesting liquor contain only 0·11 grain of solid matter, while 49 grains of albumen, when dried, leave about 10 grains of solid matter, it follows that one grain of pepsin is capable of causing the solution of 100 grains of dry albumen.

When pepsin liquor is employed to dissolve albumen, it partly loses its digesting power. Hence it must suffer an alteration during the process.

It acts best at the temperature of 100°. But it will act also at 54° or 55°, though not so well.

When the albumen has been previously reduced to a fine powder, it is dissolved in from six to twenty-four hours. Fibrin is dissolved in from three to twelve hours. The presence of atmospherical air is not necessary for these solutions, and no gas is given out. Some salts, sulphate of soda, for example, hinder the digesting action of pepsin.

The solution of albumen in the pepsin liquor consists, according to Schwann, of, 1. Altered albumen dissolved in the acid, and precipitable by neutralizing that acid; 2. Of osmazome; 3. Of salivin. Flesh, both raw and roasted, is also dissolved by the pepsin liquor; but the process is slower.*

Vogel has shown that pepsin is not formed by the action of the acid upon the mucous membrane of the stomach. For if we digest the mucous membrane in pure water we obtain a liquor which possesses digestive properties. Other acids produce the same effect as the muriatic. Vogel tried the sulphuric, acetic, phosphoric, and nitric acids successfully. Phosphoric acid answered best, and nitric acid worst of all these acids.†

Vogel examined also the changes produced upon albumen and fibrin when dissolved in the pepsin liquor. It had been shown by Eberlé and Schwann, that the albumen, after being so dissolved, was not coagulated by heat, and was partly soluble in alcohol. The solution is muddy. Alcohol increases the muddiness somewhat. Tannin throws down an abundant brownish-

* Schwann, Poggendorf's Annalen, xxxviii. 358.
† Jour. de Pharmacie, xxv. 648.

white precipitate. Prussiate of potash a bulky white, and red prussiate a green precipitate. Carbonate of soda throws down a white gelatinous precipitate, soluble in water and alcohol. The liquor is still precipitated by tannin but not by prussiate of potash. It is also precipitated by acetate of lead and by a solution of alum. Corrosive sublimate throws down a bulky white precipitate, and sulphate of copper an abundant greenish-blue powder. Vogel analyzed this last precipitate, and found the albumen unaltered in its chemical constitution. Nor does the fibrin dissolved in the pepsin liquor seem to have changed its nature.*

From the preceding detail, which has been lengthened out in consequence of the obscurity of the subject, it appears that the gastric juice is secreted only when the stimulus of food is applied; that it is a clear transparent liquid containing as essential ingredients, about 2¾ per cent. of muriatic acid, and a certain proportion of pepsin which has not been determined. Whether the pepsin of the gastric juice be analogous to *amygdalin* of the almond, has not been determined. It is much more probable that it is a substance quite peculiar, formed in the stomach for the express purpose of converting the food into chyme.

CHAPTER V.

OF THE PANCREATIC JUICE.

THE *pancreas* is a conglomerate gland resembling closely in its appearance the parotid. It is about the size of a dog's tongue, and extends from the spleen to the curve of the duodenum, resting over the spine. The duct, which conveys the liquid secreted by the pancreas, was first demonstrated by John George Wirsung of Bavaria in 1641; though it is stated by Haller that it was pointed out to Wirsung by Maurice Hoffmann. Be that as it may, Regnier de Graaf collected the gastric juice of a dog in 1664, and endeavoured to determine its nature. He opened the duodenum, introduced a quill into the pancreatic duct, and allowed the liquid to pass through it into a bottle. He describes it as limpid and acidulous, or most commonly acidulo-saline.

* Jour de Pharmacie, xxv. p. 652.

It was afterwards collected and examined by Schuyl, Wepfer, Pechlin, Brunner, and J. Bohn ; the first of whom confirmed, while the others combated the opinions of De Graaf. But, from the infant state of chemistry at the time when they lived, their examinations could scarcely lead to any satisfactory result.

After some progress had been made in the investigation of animal fluids, a few observations on the pancreatic juice were made by Mayer. Magendie also attempted to collect it, though he succeeded in obtaining only a few drops. He found it yellowish, saline, alkaline, and coagulable by heat.*

The most celebrated physiologists of the last century, Hoffmann, Stahl, Boerhaave, Haller, &c. concur in opinion, that the pancreatic juice is of a similar nature with saliva. And this opinion, founded on the similar appearance of the pancreas and parotids, was generally adopted. The experiments of Tiedemann and L. Gmelin, detailed in their work on *digestion*, have at last given us some facts, which will enable us to decide this long disputed point.

They collected the pancreatic juice of the dog, the sheep, and the horse, by the same method which had been previously employed by De Graaf, and which succeeded with them perfectly; though it had failed with Magendie.

It appears from their experiments, that the quantity of pancreatic juice secreted is not large. They found it always acid when the animal was in full vigour; but when its health and strength were enfeebled by the painful situation in which it was placed, the pancreatic juice became alkaline. In four hours they collected from the pancreas of a large dog 154 grains of pancreatic juice. After the experiment was finished, the glass tube through which the juice had flowed was withdrawn, the excretory duct was tied up, the viscera replaced in the abdomen, and the external wound closed by sutors. The animal gradually recovered, and continued in perfect health for eleven weeks. He was killed, and the state of the excretory ducts of the pancreas examined. There were two pancreatic ducts in that dog. The larger had been tied up, but the smaller, which entered the duodenum along with the *ductus communis choledochus*, supplied its place.

The pancreatic juice thus collected was opal coloured, and was

* Physiologie, ii. 367.

thready, resembling white of egg diluted with water. It coagulated when boiled, and likewise when mixed with nitric acid or with alcohol. The first portion collected was acid, the last portion alkaline, and was composed of,

Water,	91·28
Solid matter,	8·72
	100·

The solid matter consisted of osmazome, of a peculiar animal matter, coloured red by chlorine, and discoloured by a larger quantity of that reagent, and of casein and albumen. When this solid matter was incinerated, it left carbonate of soda and chloride of sodium, with a trace of sulphate and phosphate of soda, and of carbonate and phosphate of lime.

The analysis of the pancreatic juice of the dog gave,

Substances soluble in alcohol,	3·68
Substances only soluble in water,	1·53
Coagulated albumen,	3·55
Water,	91·72
	100·48

From this analysis it appears that the pancreatic juice of the dog has no resemblance to saliva. The substance rendered red by a little chlorine was soluble in alcohol and not in water. It constitutes the peculiar and characteristic constituent of pancreatic juice, and is therefore called *pancreatin.*

The pancreatic juice of the sheep was similar in appearance to that of the dog, but more watery, the solid matter in it amounting only to 3·65 per cent. This liquid was found to contain,

Matters soluble in alcohol,	1·51
Matters soluble in water only,	0·28
Coagulated albumen,	2·24
Water,	96·35
	100·38

From the solid matter they extracted osmazome and casein, besides the coagulated albumen. Whether any pancreatin existed in it was doubtful. At any rate, the quantity was too small to be detected.

The pancreatic juice of the horse was obtained from a horse

which just before its death had eaten a quantity of oats. It had a yellowish colour, was transparent, but slightly opaline, mucilaginous, and thready like white of egg. It slightly reddened tincture of litmus, coagulated by boiling, even after having been diluted with water. It was therefore quite analogous to the pancreatic juice of the sheep.*

From these experiments it follows that saliva and pancreatic juice are different in their properties.

1. The solid matter in pancreatic juice of the dog is at least twice as great as that in saliva.

2. Saliva contains mucus and salivin. If albumen or casein be present, the quantity must be exceedingly minute; but pancreatic juice contains a great deal of albumen and casein, and no salivin or mucus.

3. Saliva is usually slightly alkaline, but pancreatic juice contains a little free acid.

4. The saliva of the sheep and of smokers contains sulphocyanic acid; but there is no trace of it in the pancreatic juice of the same animal.

5. The presence of casein in pancreatic juice was inferred, because this juice is not only precipitated by acids but by metallic salts and the tincture of nut-galls; but as albumen is precipitated by these reagents as well as casein, the evidence for the existence of this last substance is not satisfactory. Should its presence be hereafter proved by experiment, it is not unlikely that its office may be to remove the pepsin from the chyme, which may be necessary in order to its conversion into chyle.

CHAPTER VI.

OF BILE.

THE *bile* is secreted by the liver, the largest of all the abdominal viscera, and it makes its way into the duodenum by the *ductus communis choledochus*. In man, the *ductus communis* and the pancreatic duct usually enter the duodenum together, but in the dog the pancreatic duct is commonly a good way lower down than the biliary duct.

* Recherches sur la Digestion, i. 26.

The liver is supplied with blood partly by the hepatic artery and partly by the *vena portæ,* which enters the liver at the great fossa, and brings to it the venous blood sent back by the principal abdominal viscera. The *vena portæ* after entering the liver subdivides into numerous branches like an artery, and there can be little doubt that the blood which it supplies is employed in the formation of bile, while the use of the blood which is supplied by the hepatic artery is to nourish the liver. That the liver is composed of globules like the other conglobate glands was first pointed out by Malpighi. The best account of the structure of this viscus has been given by Mr Kiernan.*

The hepatic ducts can be traced along the canals in the fissures between the lobules and into the lobules where they form plexuses. The branches of the portal vein and the hepatic arteries also enter the lobules. The venous branches forming a plexus which communicates with the incipient radicles of the hepatic vein, and the arteries, which are very few and minute, are the nutrient vessels of the lobules. The branches of the artery ramify freely upon the coats of the portal vein and on the hepatic ducts, furnish materials for the nutrition of both, and to the latter for the secretion of mucus, which lubricates their interior coat.

Each lobule of the liver is found to consist of a reticulated plexus formed by the minute radicles of the biliary ducts. For these, when examined with a highly magnifying power, are seen to divide and subdivide so as to form a mesh in its interior, which is supported by a cellular tissue, furnished by Glisson's capsule. Upon this mesh is disposed another formed by the terminal branches of the *vena portæ.* It is difficult to inject the ducts, owing to their being filled with bile. Mr Kiernan succeeded by first tying the portal vein and hepatic artery in a living animal after feeding it. Thus the secretion of bile was suspended, and that which the ducts contained discharged. The ducts cannot be injected directly from the hepatic vein; for no branches from this vessel ramify on their coats. The residue of the blood conveyed by the hepatic artery to the lobules, to the different vessels and to the ducts for their nutrition, is taken up by the minute veins, and conveyed to the *vena portæ;* so that part of the blood from which bile is secreted is derived from the liver itself.†

* Phil. Trans. 1833, p. 711.

† See Quain's Anatomy, p. 650, and Kiernan's paper, as quoted above.

Bile, after being secreted in these lobules of the liver, is conveyed by the small ducts to larger and larger ducts, till they at last unite in one duct called the *ductus hepaticus*. In many animals there is a cavity placed on the liver called the *gall-bladder*, into which the bile makes its way from the hepatic duct, when not wanted for digestion. The duct by which it enters is called the *ductus cisticus*. It joins the hepatic duct before it enters the duodenum, and both together form one common duct called the *ductus communis choledochus*.

From the large size of the liver and of the biliary ducts, the quantity of bile thrown into the duodenum must be considerable; though it has not been in the power of physiologists to form any accurate estimate of it. According to Leuret and Lessaigne,* the bile secreted by the liver of the horse amounts to two ounces in a quarter of an hour. This would make the enormous quantity of twelve pounds a-day. But as the horse has no gall-bladder, it is probable that bile is only secreted, or at least given out by the liver, when that organ is excited by the stimulus of chyme in the small intestines.

Great attention has always been paid to this secretion by medical men. The ancients ascribed a number of diseases and even affections of the mind to its agency. Various observations on it were made by Boyle, Boerhaave, Varheyen, Ramsay, and Baglivi.

The first attempt to examine it seems to have been made by Neumann.† He describes the characters of ox-bile, and says, that it is neither acid, nor alkaline, nor soapy. It is coagulated by acids, and slightly precipitated by carbonate of potash. Ammonia occasions no alteration. Rectified spirits scarcely make it cloudy. He subjected it to distillation, and noticed some of the products, viz. water, ammonia, and oil. The residue contained a fixed alkali.

Cadet in his analysis of bile,‡ published in 1767, added some new facts. Alcohol throws down a substance from bile, which he considered as *gelatin*. He shewed that the alkali in bile is soda.

Van-Bochoute, Professor at Louvain, wrote in 1778 a Latin dissertation containing important observations respecting the na-

* *Recherches Physiologiques et Chimiques pour servir a l'histoire de la digestion*, p. 83.

† I quote from Lewis's translation, p. 566. This translation was published in 1759, and contains much original matter.

‡ Mem. Paris, for 1767, p. 471.

ture of this liquor, the oily matter, and the means of separating all the materials which constitute it.*

Thenard made an analysis of ox-bile, which was published in 1805.† According to this analysis, the constituents of ox-bile are as follows:

Water,	700·0
Picromel and resin,	84·3
Yellow matter,	4·5
Soda,	4·0
Phosphate of soda,	2·0
Common salt,	3·2
Sulphate of soda,	0·8
Phosphate of lime,	1·2
Oxide of iron, trace.	
	800·0

According to Thenard, the picromel constitutes the essential constituent of bile. He obtained it by precipitating bile by means of acetate of lead. The lead was separated from the picromel by sulphuretted hydrogen; or it may be precipitated from bile by sulphuric acid. The green precipitate thus obtained was formerly called resin of bile. When it is digested in water over carbonate of barytes, the picromel dissolves in the water in proportion as the sulphuric acid is separated by the barytes. Picromel thus obtained has a greenish-yellow colour, a bitter taste, and resembles inspissated bile in its appearance.

The yellow matter is the substance to which Van Bochoute gave the name of *fibrin*, and which was considered by others as *albumen*. It is probably mucus.

In his second memoir, Thenard takes a view of the nature of the bile in different animals, and on the formation of biliary calculi. He states the constituents of human bile to be:

Water,	91·
Insoluble yellow matter,	0·18 to 0·91
Albumen,	3.81
Resin,	3·74
Soda,	0·51
Salts,‡	0·41
	99·65

* Fourcroy's *System*, x. 26. † Mem. d'Arcueil, i. 23 and 46.

‡ The salts were phosphate, sulphate, muriate of soda; phosphate of lime, oxide of iron.

Berzelius analyzed bile in 1808, and gave the result in the second volume of his *Animal Chemistry*.* According to this analysis, the constituents of the bile are as follows:

Water,	908·4
Biliary matter,	80·0
Albumen,	3·0
Soda,	4·1
Phosphate of lime,	0·1
Common salt,	3·4
Phosphates of soda and lime,	1·0
	1000·0†

He afterwards made some corrections on his analysis, and in his Traité de Chimie, (vii. 189), gives the constituents of bile as follows:

Water,	904·4
Biliary matter, (including fat),	80·0
Mucus of gall-bladder,	3·0
Extract of meat, common salt, and lactate of soda,	7·4
Soda,	4·1
Phosphates of soda and lime, trace of substance insoluble in alcohol,	1·1
	1000·0

It is obvious that the biliary matter of Berzelius and the picromel of Thenard constitute one and the same substance.

Dr Prout analyzed the bile in the same way as Berzelius, and obtained similar results.

Tiedemann and Gmelin published their work on *digestion* in 1825. They made a great many experiments on ox-bile, and likewise on the bile of other animals. From ox-bile they extracted no fewer than twenty-three different substances, which they distinguished by the following names:

1. An odorous principle.
2. Cholesterin or biliary tallow.
3. Biliary resin.
4. Biliary asparagin or taurin.
5. Picromel.

* Djurkemie, ii. 48.

† Berzelius does not mention the animal whose bile this is an analysis of. I presume it was ox-bile.

6. Colouring matter.

7. A substance containing much azote, slightly soluble in water; insoluble in cold, but soluble in hot alcohol.

8. Gliadin? insoluble in water, but soluble in hot alcohol.

9. Osmazome? soluble in water and alcohol, precipitated by infusion of nut-galls.

10. A substance emitting when heated a urinous smell.

11. Casein.

12. Mucus.

13. Bicarbonate of ammonia.

14 to 20. Margarate, oleate, acetate, cholate, bicarbonate, phosphate, and sulphate of soda, (with some potash).

21. Common salt.

22. Phosphate of lime.

23. Water, amounting to 91·51 per cent.*

There can be no doubt that the taurin of Gmelin was formed from the biliary matter of Berzelius during the processes to which it was subjected.

Bile is a liquid of a greenish-yellow colour. Its taste is very bitter, but at the same time sweetish, having some resemblance to the taste of liquorice sugar. Its smell is weak, but peculiar and disagreeable. It does not alter the colour of vegetable blues. Its consistence varies very much; sometimes it is a thin mucilage, sometimes very viscid and glutinous. Sometimes it is transparent, and sometimes it contains a yellow matter, which precipitates when the bile is diluted with water.

Its specific gravity varies, as is the case with all animal fluids. According to Hartmann it is 1·027;† according to Thenard 1·026 at the temperature of 43°. Berzelius states the mean specific gravity at 1·025.‡ When strongly agitated it lathers like soap. It mixes with water in any proportion, and assumes a yellow colour. But it refuses to unite with oil. Yet it dissolves soap readily, and is often employed to free cloth from greasy spots. When distilled to dryness, it becomes at first slightly muddy; then it froths violently, and a colourless liquor passes into the receiver, having a smell similar to that of bile, and slightly precipitated by diacetate of lead. The residue in the retort when

* Recherches, &c. i. 42. † Haller's Physiol. vi. 546.

‡ Djurkemie, ii. 45.

4

well dried amounts to one-eighth or one-ninth of the original quantity of bile.

Ox-bile has been long used as a substitute for soap to remove stains from carpets, woollen cloths, &c. On that account it was considered by the iatro-chemists as a soap or a compound of an animal oil and an alkali. The alkali was ascertained to be soda; and this soda was, of course, united to an oily acid, which converted it into soap. This view was considered as overturned by the experiments of Thenard. Berzelius's analysis was not incompatible with the soapy nature of bile; though he does not appear to have considered the liquid in that point of view.

It was shown by M. Demarçay in 1838 that the old opinion of the soapy nature of bile, supported by Cadet, is, after all that has been said to the contrary, the true one. He has proved that the essential constituents of bile are soda, and an oily acid combined with the soda, which he has distinguished by the name of *choleic acid*,* and of which an account has been given in a previous part of this volume.†

We possesss but little information respecting the bile of birds. Tiedemann and Gmelin found it very different in different species, and even in those of the same species. Sometimes it was greenish-blue, sometimes emerald green, and sometimes verdigris green. In fowls and ducks it was so glutinous, that it could be drawn into long threads, and it contained mucous clots. They even made an analysis of the bile of a duck. They found the salts the same as in ox-bile; and it is probable, from their experiments, that it consists essentially of choleate of soda, though no experiments are stated from which the properties of the choleic acid can be determined.‡

According to Tiedemann and Gmelin, the bile contained in the gall-bladder of the *Rana temporaria* amounted to only a few drops. It was yellowish-green, transparent, and very liquid. Its taste was sweetish and much less bitter than the bile of fishes. When mixed with solution of potash, it becomes muddy, and yellow flocks precipitate.

* Ann. de Chim. et de Phys. lxvii. 177.

† It is not unlikely that, besides choleic acid, bile may contain some other oily acid. At least, Demarçay made no attempt to determine whether some other acid was not present.

‡ Recherches sur la Digestion, ii. 158.

The gall-bladder of the *Coluber natrix*, according to the same chemists, contained a gramme (15·433 grains) of bile, which was grass-green, transparent, and very liquid.

Berzelius made some experiments upon the bile of the *Python amethystinus*, a snake from Bengal, which died accidentally at Stockholm.* It had a deep-green colour passing into yellow. When partially evaporated, it left a transparent mass having the same colour, soft, but very viscid, and completely soluble in water. He found it to contain biliary matter, doubtless choleates of potash and soda, colouring matter, a substance capable of crystallizing, a substance analogous to salivin, albumen, fatty acids, and certain salts.

Tiedemann and Gmelin analyzed the bile of several fishes, but the facts ascertained do not seem of sufficient importance to be detailed.

CHAPTER VII.

OF CHYLE.

Owing to the small size of the lacteals, and the consequent difficulty of collecting their contents in any quantity, the properties of *chyle*, as it is when just absorbed from the intestines, are but imperfectly known. In the mammalia it is opaque and white as milk; in birds and fishes it is nearly transparent and colourless.

MM. Emmert and Reuss, about the year 1808, made a set of experiments on the chyle of the horse, which was published in 1811 in the *Annales de Chimie* (lxxx. 81.) They collected the chyle from different parts of the thoracic duct. The chyle in the lacteals was white like milk, while that in the thoracic duct was of a pale-yellow colour. It had the consistence of serum of blood, a saline taste, and a peculiar smell. It assumed a pink colour on exposure to the air, resembling a mixture of milk with some drops of blood. It coagulated when exposed to the air, but slowly and imperfectly. We see, from these observations, imperfect as they are, that chyle has considerable resemblance to blood. It coagulates spontaneously like blood, and therefore contains a sub-

* Poggendorf's Annalen, xviii. 87.

stance analogous to the globules of blood, though not red. The uncoagulated portion coagulated by heat, and therefore contained albumen.

The chyle from the sublumbar branches of the thoracic duct of horses was examined likewise by Emmert and Reuss, and also by Vauquelin.* It was white and opaque like milk, and contained a white and opaque coagulum. The liquid portion was coagulated by heat, by acids, and by alcohol; and therefore contained albumen. There was also an alkali in it, as it restored the blue colour of litmus-paper reddened by an acid. Hot alcohol dissolved a fatty matter from the coagulum. The portion which coagulated spontaneously contained characters analogous to those of *fibrin*.

Dr Marcet and Dr Prout examined, in 1815, the chyle of two dogs, one of which had been fed entirely on vegetable food, the other on animal food.†

Dr Marcet described the chyle of the dog fed on vegetable food in the following terms: Soon after being collected it was a semitransparent, inodorous, colourless fluid, having but a very slight milky hue, like whey diluted with water. Within this fluid there was a coagulum or globular matter, which was also transparent and nearly colourless, having the appearance and consistence of albumen ovi, or of those gelatinized transparent clots of albuminous matter, which are sometimes secreted by inflamed surfaces. This mass had a faint pink hue, and minute reddish filaments were observed upon its surface. It did not, as Dr Prout ascertained, affect litmus or turmeric paper, nor did it coagulate milk. The coagulum, when separated from the serum, parted readily with its serosity or fluid portion, and was at length reduced to a very small size. The specific gravity varied from 1·0215 to 1·022. The portion of solid matter including salts varied in different specimens of chyle from 4·8 to 7·8 per cent.

Both Dr Marcet and Dr Prout found the chyle of the dog fed on animal food agreeing with that of the dog fed on vegetable food, except that, instead of being nearly transparent and colourless, it was white and opaque like cream. The coagulum was also white and opaque, and had a more distinct pink hue, with an appearance not unlike that of very minute blood-vessels. The coagulum gradually yielded farther quantities of serous fluid,

* Ann. de Chim. lxxxi. 113. † Annals of Philosophy, xiii. 12.

till nothing remained but a small quantity of pulpy opaque substance, in appearance somewhat similar to thick cream; and containing minute globules, besides the red particles already noticed. The residue of the coagulum became quite putrid in the course of three days, while that obtained from vegetable chyle in a similar manner had not yet begun to undergo that process. Dr Prout analyzed these two specimens of chyle, and obtained the following results:

	Vegetable food.	Animal food.
Water,	93·6	89·2
Fibrin,	0·6	0·8
Incipient albumen?	4·6	4·7
Albumen with red colouring matter,	0·4	4·6
Sugar of milk?	trace.	—
Oily matter,	trace.	trace.
Salts,	0·8	0·7
	100·0	100·0

Nearly the same modes of operating were adopted in the analysis of both specimens.

The water was determined by evaporating a given weight of chyle upon the water-bath.

The coagulum was repeatedly washed with cold water till it ceased to give any thing to that liquid. The residue was considered as *fibrin.* The only peculiarity in this substance was that it dissolved with greater difficulty in acetic acid than fibrin from blood.

To the serous portion dilute acetic acid was added, and the mixture was raised to the boiling point. A precipitate fell, which was also thrown down by corrosive sublimate. It was not albumen nor casein. This is the substance called in the preceding table *incipient albumen.*

After the preceding substance had been removed by filtration, prussiate of potash was added to the acetic solution. A precipitate fell, which was considered as albumen.

Dr Prout ascertained that the albumen in chyle coagulates when heated to 149°, which is ten degrees lower than the coagulating point of the albumen in the blood.

Leuret and Lassaigne examined the chyle from a variety of animals, chiefly dogs and horses. They assure us that, whatever

the nature of the food was, the constituents of the chyle were always the same. They constantly obtained fibrin, albumen, fatty matter, soda, common salt, and phosphate of lime; though the proportions of these constituents vary much according to circumstances.*

Dr G. O. Rees subjected the chyle from the lacteals of a young ass, taken out immediately after death, to analysis and obtained,

Water,	902·37
Albuminous matter,	35·16
Fibrin,	3·70
Alcoholic extractive,	3·32
Aqueous extractive,	12·33
Fatty matter,	36·01
Salts,	7·11
	1000·00

The salts were alkaline chloride, sulphate and carbonate, traces of phosphate; oxide of iron. The oxide of iron was found in considerable quantity in the aqueous extractive matter.†

CHAPTER VIII.

OF LYMPH.

The lymph is conveyed from all the cavities of the body by a set of vessels called *lymphatics*, discovered by Olaus Rudbeck, in the year 1651. The discovery was also claimed by Thomas Bartholin. But it is now universally admitted that Rudbeck had the priority. These vessels, called also *absorbents*, are transparent, and their coats are very thin. They are very small, and do not increase in size by the conflux of branches. Appended to them are a number of nodular bodies called *glands* or *ganglions*. These bodies in the extremities are usually found at the flexures of joints; but in the cavities they are variously disposed. When the vessels arrive at these glands, they become intimately connected with them, and seem to ramify through their interior. It would be difficult to convey an accurate idea of the course

* Recherches, &c. p. 158. † Phil. Mag. (3d series,) xviii. 156.

which these vessels take from the extremities to the thoracic duct in which they terminate. But excellent plates of them were published by Mascagni in 1790, to which the reader is referred for a correct idea of their course.

These vessels convey away a liquor which is exhaled from all the serous membranes of the body, in order to lubricate these surfaces, and keep them in a state proper for performing their respective functions in the living body. What the amount of this liquid is we have no means of determining, but it is conveyed by the lymphatics from all the cavities where it is generated and conducted by them to the thoracic duct, where it is mixed with the chyle and conveyed along with it into the blood. When the quantity of lymph secreted exceeds that carried off by the lymphatics it accumulates in these cavities, and produces the disease called dropsy.

According to M. Collard de Martigny, lymph scarcely flows into the thoracic duct during the process of digestion, but it does when that process is at an end. The flow increases and the vessels become turgid by fasting; but when abstinence is continued till death ensues, the lymphatics are destitute of lymph.*

Reuss and Emmert† examined the lymph of a horse in 1799. It was transparent, and had a pale-yellow colour, with a slight tint of green. When examined by a powerful microscope, no globules nor any other substance of a determinate form could be distinguished in it. It was a liquid apparently homogeneous, without smell, but having a slight taste similar to that of the serum of blood. In about a quarter of an hour after it was taken out of the vessels, it coagulated into a colourless jelly, which gradually contracted and swam in a yellowish liquid. This coagulum was considered as similar to the fibrin of blood: 92 grains of lymph yielded one grain of fibrin, weighed while moist; so that the quantity of dry fibrin in lymph cannot amount to $\frac{1}{300}$th part. The residual serum being evaporated to dryness left 3·25 per cent. of dry residue, consisting principally of albumen, which remained undissolved when the dry residue was washed with water. When this water was evaporated crystals of common salt were deposited.

Lymph from the neck of a horse was examined by Lassaigne

* Journ. de Physiologie, viii. 174. † Scherer's Journ. v. 691.

in 1825.* It was transparent, yellowish, without smell, and had a saline taste. It coagulated spontaneously both in vacuo and when exposed to the air. The coagulum was colourless fibrin. Lassaigne states the constituents of lymph to be,

Water,	925·00
Fibrin,	3·30
Albumen,	57·36
Common salt, chloride of potassium, Soda, phosphate of lime,	14·34
	100·00

This analysis, though imperfect, shows a close resemblance between lymph and chyle.

Mr Brande in 1812 made a few observations on the lymph taken from the thoracic duct of animals that had been kept for twenty-four hours without food.† It was miscible with water in every proportion, did not alter vegetable colours; it was neither coagulated by heat, nor acids, nor alcohol, but it was rendered slightly turbid by the last reagent. When evaporated to dryness it leaves a very small residue, which changes violet-paper to green. The ashes contained a minute portion of common salt, but no iron.

Mr Brande does not inform us from what animal this lymph had been obtained. It differed in its characters from the lymph examined by Reuss and Emmert, and by Lassaigne.

In the winter of 1831–2, Professor Müller of Bonn had an opportunity of examining pure lymph. It issued from a small wound in the back part of the foot of a young man. This wound would not heal. When the back of the great toe behind the wound was pressed, a quantity of clear liquid issued out, sometimes in a jet. This liquid was lymph. In about ten minutes it deposited a coagulum of fibrin in a form resembling a spider's web. The lymph, though clear and transparent, yet, when examined by the microscope, was found to contain numerous colourless globules. They were smaller, and not so numerous as the globules in the blood. Some of these globules united with the coagulum; but the greatest part remained suspended in the liquid portion.

* See Berzelius's Traité de Chimie, vii. 128. † Phil. Trans. 1812, p. 96.

The coagulum did not consist of globules, as is the case with the crassamentum of the blood. It had originally been in solution in the liquid, while the globules were suspended in it. The globules separated and contained in the coagulum might be seen scattered through it, and these were much smaller than the globules that still remained in suspension in the liquid.

Professor Müller gives a method of obtaining pure lymph from the frog. When the skin is removed from the thigh of a large frog, and the muscles laid bare without wounding any large blood-vessel, a clear, colourless, salt-tasted lymph flows out. It contains $\frac{1}{81}$ of fibrin. If the frog has fasted long no lymph can be got by this process. The globules in the lymph of the frog are exceedingly small. Lymph in the lymphatic vessels is commonly colourless, in those of the spleen it is reddish. We know little about the motion of the lymph. Müller describes an organ which he considers as connected with that motion.*

A quantity of lymph from a wound after the removal of the foot was collected and examined by MM. Marchand and Colberg.† About 1½ gramme was collected in twelve hours. Its specific gravity was 1·037. It gradually deposited a thin web of fibrin, amounting to about half a per cent. of the lymph. The opalescent liquid above it had a yellow colour, and the consistence of almond oil. Its constituents, as determined by these Chemists were,

Water,	96·926
Fibrin,	0·520
Albumen,	0·434
Osmazome and loss,	0·312
Fat oil, / Crystalline fat,	0·264
Chloride of sodium, / Chloride of potassium, / Carbonate and lactate of potash, / Sulphate of lime, / Phosphate of lime, / Oxide of iron,	1·544
	100·000

* Poggendorf's Ann. xxv. 513. † Ibid. xliii. 625.

A quantity of lymph, taken from the absorbents of a young ass immediately after death, was analyzed by Dr G. O. Rees. He states its constituents to be,

Water, .	965·36
Albuminous matter, .	12·00
Fibrin, .	1·20
Alcoholic extractive, .	2·40
Aqueous extractive, .	13·19
Fatty matter, a trace.	
Salts, .	5·85
	1000·00

The salts were alkaline chloride sulphate, carbonate; traces of a phosphate; oxide of iron.*

As the liquid which collects in the cavities of the body during dropsy is undoubtedly of a similar nature with lymph, being the liquid which the lymphatics in ordinary health absorb, though probably from the increased quantity it is more diluted with water, some light may perhaps be thrown upon the nature of lymph by stating the constituents of the liquor of dropsy as they have been determined by chemical analysis.

1. *Liquor of blisters.*—This liquid is transparent and colourless when the blisters are natural. When they are raised artificially by the application of cantharides, the liquor has a yellowish colour, and the smell of the blistering plaster. By Margueron's analysis, it is analogous to serum of blood, consisting of,

Water, .	78
Albumen, .	18
Common salt, .	2
Carbonate of soda,	1
Phosphate of soda,	1
	100·†

2. *Liquor of hydrocephalus internus.*—This liquid, which was limpid and colourless, was analyzed by M. Barruel, who obtained,

* Phil. Mag. (3d series,) xviii. 156. † Ann. de Chim. xiv. 225.

Water,	.	990·0
Albumen,	.	1·5
Osmazome,	.	0·5
Common salt,	.	6·5
Phosphate of soda,	.	0·5
Carbonate of soda,	.	1·0
		1000·0*

3. *Guttural ganglions of the horse.*—The liquid in these ganglions was examined by Lassaigne,† and found to contain,

Fibrin, a great deal.
Coagulated albumen, a little.
Soluble albumen.
Traces of fatty matter.
Phosphate and carbonate of lime.

It was observed by M. Gaspard, that when men were obliged, from want of proper food, to feed on grass and green herbs, anasarca was the consequence.‡

4. *Liquor of the pericardium.*—This liquor, obtained from the pericardium of a boy who died suddenly, was examined by Dr Bostock.§ It had the colour and appearance of the serum of blood. When evaporated to dryness it left a residuum amounting to $\frac{1}{12}$th of its weight. When exposed to the heat of boiling water it became opaque and thready. It was abundantly precipitated by corrosive sublimate before boiling, but after boiling and filtering it was not affected by this reagent. Hence it evidently contained albumen. It yielded,

Water,	.	92·0
Albumen,	.	5·5
Mucus,	.	2·0
Common salt,		0·5
		100·0

5. *Liquor from spina bifida.*—This liquid also was examined by Dr Bostock.‖ It was slightly opaque, and did not alter vegetable blues. Heat increased its opacity, but did not coagulate it. It contained,

* Jour. de Physiol. i. 98.
† Ibid. p. 391
‡ Ibid. p. 237.
§ Nicholson's Journal, xiv. 147.
‖ Nicholson's Jour. xiv. 145.

Water,	97·8	
Common salt,	1·0	
Albumen,	0·5	
Mucus,	0·5	proportions conjectural.
Gelatin?	0·2	proportions conjectural.
Lime, trace.		
	100·0	

6. *Liquor of ascites.*—This liquid obtained in the usual way by tapping was examined by M. Dulong Junr.* It was clear and limpid, had the consistence of white of egg, and frothed when agitated. It restored the blue colour of reddened litmus-paper. Potash and soda occasioned a slight smell of ammonia. Heat and alcohol coagulated it completely. Its constituents were,

Water,	70·38
Albumen,	29·00
Common salt,	0·28
Soda,	0·14
Gelatin or altered albumen,	0·20
Ammonia, trace.	
	100·00

This liquid contained more albumen than the serum of blood. Probably it was contained in a cyst, and a portion of its water had been withdrawn by the absorbents.

7. *Another liquid of ascites.*—This liquid, which exhibited some remarkable characters, was examined by M. Coldefy-Dorly, apothecary at Cressy.†

It was brown, very viscid, without smell and tasteless; did not alter vegetable blues. It held in suspension a great number of brilliant crystals, which the viscosity of the liquid prevented from subsiding. When heated it coagulated. Sulphuric, muriatic, and especially nitric acid caused a copious precipitate. Alkalies increased the intensity of the colour, and rendered the liquor more fluid; but did not disengage any ammonia. From 100 parts of it subjected to analysis, the following constituents were obtained:

* Jour. de Pharmacie, xi. 140. † Ibid. p. 401.

Albumen,	4·80
Common salt,	0·52
Chloride of calcium,	0·04
Uncrystallizable sugar,	0·24
Fatty matter,	0·20
Mucus,	0·24
	6·04

Besides traces of sulphur, muriatic acid, and a colouring matter intimately united to albumen.

8. *Another liquor of ascites.*—This liquor was extracted by tapping for the third time the abdomen of a female fourteen days before her death. It was examined by M. Marchand.*

It was a yellow-coloured liquid, transparent, without smell, and having a weak salt taste. Its constituents were,

Water,	95·22
Albumen,	2·38
Urea,	·42
Carbonate of soda,	0·21
Phosphate of soda,	0·06
Common salt,	0·82
Mucus and loss,	0·89
Sulphate of soda, trace.	
	100·00

9. *Liquor from the vertebral column of a horse.*—This liquid was analyzed by Lassaigne, who states its constituents to be,

Water,	98·180
Osmazome,	1·104
Albumen,	0·035
Common salt,	0·610
Carbonate of soda,	0·060
Phosphate of lime,	0·009
Carbonate of lime, trace.	
	99·998†

These analyses are, of course, imperfect. They show a certain analogy between these liquids and serum of blood; but it

* Poggendorf's Annalen, xxxviii. 356. † Jour. de Physiologie, vii. 82.

follows from them that not merely the ratios, but the constituents themselves had been altered by disease.

CHAPTER IX.

OF MILK.

Milk is a fluid secreted by the female of all the animals belonging to the class of *Mammalia*, and intended evidently for the nourishment of her offspring.

The milk of every animal possesses certain distinctive peculiarities, but the milk which, from time immemorial, has been chiefly used by man as an article of food is that of the *cow*. It will be proper, on that account, to give, in the first place, an account of that milk. We may afterwards point out the characteristic distinctions between it and that of other animals.

We have only to open the Old Testament or the writings of Homer, to be satisfied at how early a period the milk of the cow was used as an article of food. Herodotus informs us that the common drink of the Scythians in his time was the milk of mares.* It appears from the same passage of Herodotus that the Scythians were acquainted with the mode of making butter. And Hippocrates, whose era was not much later than that of Herodotus, describes their process very clearly: "The Scythians," says he, "pour the milk of their mares into wooden vessels, and shake it violently. This causes it to foam, and the fat part, which is light, rising to the surface, becomes what is called butter (βουτυρον). The heavy or thick part, which is below, being kneaded and properly prepared, is, after it has been dried, known by the name of hippace (ἱππακη). The whey, or serum, remains in the middle.† Hippocrates, as appears from this passage, was acquainted with butter. He gives it in his writings the name of *pickerion* (πικεριον). This seems to have been the old Greek name for butter. But it went out of use, and the term βουτυρον came in its place.

There is no evidence that butter was known to the ancient Hebrews. What is translated *butter* in the Septuagint, and that translation has been adopted in our Bible, is admitted to have meant *cream*, and not butter. It was known to the Greeks soon

* Melpomene, cap. 2. † De Morbis, lib. iv. p 67. Edit. 1595.

after the time of Hippocrates, but that people do not seem to have used it as an article of food. It is obvious, from what Pliny says, that even in his time butter was but little used by the Romans. "It is surprising," says he, "that the barbarous nations which live upon milk should for so many ages have been ignorant of or have despised cheese, thickening their milk into an unpleasant acid matter and into fat butter.* Cheese seems to have been known to the Greeks and Romans at an early period, and to have been used by them as an article of food. It is curious that Aristotle never alludes to butter in any of his writings, though he is very particular in his account of cheese.

Boerhaave considered milk as a natural *emulsion*, consisting of an oil intimately mixed with a mucilaginous substance.† Neumann considered it as analogous to chyle. He found that a pint of cow's milk when evaporated to dryness left two ounces and two drachms of residue; but he found the milk of the same cow to yield various proportions of dry residue at different times. He gives a pretty minute description of butter, cheese, sugar of milk, and whey, but takes no notice of the saline contents of that liquid, except that after combustion it leaves an alkaline ash.‡

M. Rouelle made a careful examination of the saline constituents of milk in 1772, but he obtained nothing but sugar of milk, chloride of potassium, and a very minute quantity of carbonate of potash. His results were published in the Journal de Medecine for 1773.§

In 1790, an elaborate memoir, by Parmentier and Deyeux, on the Physical and Chemical properties of the Milk of Woman, Cow, Goat, Ass, Sheep, and Mare, was published. To the authors of this memoir was awarded the prize offered by the Royal Medical Society of Paris for the best essay on the above subject. In this paper we find the first attempt at a chemical analysis of milk. It was necessarily imperfect, but it contained a great many important observations, which facilitated the labours of other chemists.‖

In the year 1804, Bouillon-Lagrange published a memoir on milk and lactic acid;¶ Scheele had long before (in 1780) made

* Plinii, Natur. Hist. lib. xi. cap. 41.

† Boerhaave's Chemistry, ii. 62, Shaw's translation.

‡ Neumann's Chemistry, p. 569.

§ See Macquer's Dictionnaire de Chimie, Art. *Lait*.

‖ See Journ. de Phys. xxxvii. 361 and 415. ¶ Ann. de Chim. l. 272.

experiments on lactic acid, and pointed out its peculiar nature.* He had also made experiments on curd, and pointed out its analogy to albumen. Bouillon-Lagrange made a pretty minute examination of the properties of curd, and endeavoured to prove that lactic acid is nothing else than acetic acid mixed with chloride of potassium, a little iron, and an animal matter.

About the year 1805, Thenard published a paper on *milk*,† in which he shows that butter may be separated from milk without the access of air. He pointed out a mode of purifying butter by fusion, and noticed some of its properties. Like Bouillon-Lagrange he considered lactic acid as merely acetic acid contaminated by animal matter. The same opinion had been advanced by Fourcroy and Vauquelin.‡

In 1808, Berzelius published the second volume of his Animal Chemistry.§ He analyzed cow's milk, and examined in detail the properties of butter, curd, and whey. The constituents of skimmed milk, according to his analysis, are,

Water,	92·875
Curd (not free from butter),	2·800
Sugar of milk,	3·500
Lactic acid and lactate of potash,	0·600
Chloride of potassium,	0·170
Phosphate of potash,	0·025
Phosphate of lime and magnesia, with a trace of iron,	0·030
	100·000

In 1830, an interesting paper was published by Braconnot on *casein*, or the curd of milk, and on the new resources which it opened to society.‖ He gives an account of the chemical properties of casein, and points out the various important uses to which it may be applied. About the same time M. Macaire-Princep made some experiments on the formation of butter.¶ In 1832, Lassaigne published a number of analyses of the milk of the cow before and after parturition;** and in 1836 M. Peligot gave a chemical analysis of the milk of the ass;†† and in 1839 we

* Scheele's Essays, p. 265.
† Nicholson's Journ. xii. 218.
‡ Mem. de l'Institut, vi. 332.
§ Djurkemie, ii. 409.
‖ Ann. de Chim. et de Phys. xliii. 337.
¶ Bibliotheque Univer. xliii. 379, or Poggendorf's Annalen, xix. 48.
** Ann. de Chim. et de Phys. xcix. 31.
†† Ibid. lxii. 432.

have a historical account by Schill of the fermentation of milk and the spirit that may be extracted from it.* A similar account had been given long before by Dr Guthrie.†

In 1839, an analysis of milk was made by M. Lecanu,‡ who got,

Butter,	36
Casein,	56
Sugar of milk, Soluble salts, Extractive,	40
Water,	868
	1000

and during the same year an elaborate chemical memoir on milk was published by MM. O. Henri and Chevalier,§ and another by M. Simon.‖

The constituents of cow's milk in a normal state are, according to the analysis of these chemists,

Casein,	44·8
Butter,	31·3
Sugar of milk,	47·7
Salts,	6·0
Water,	870·2
	1000·0¶

These proportions vary with the food. The following table shows the variation when the cows were fed with carrots and with beet:

	Carrots.	Beet.
Casein,	42·0	37·5
Butter,	30·8	27·5
Sugar of milk,	53·0	59·5
Salts,	7·5	6·8
Water,	866·7	868·7
	1000·0	1000·0**

Milk, as every body knows, is an opaque white-coloured fluid,

* Annalen der Pharmacie, xxxi. 152.
† Edin. Trans. Vol. ii.
‡ Jour. de Pharm. xxv. 201.
§ Ibid. p. 333, 401.
‖ Ibid. p. 349.
¶ Ibid. xxv. 340.
** Ibid. p. 342.

having a slight but peculiar smell, and an agreeable sweetish taste. It slightly reddens vegetable blues. Its boiling and freezing points are nearly the same as those of water; yet they vary a few degrees in the milk of different animals.* Its specific gravity is greater than that of water and less than that of blood; but it varies so much even in the milk from the same animal, that it is impossible to give a correct mean. Brisson† states the specific gravity of various milks as follows:

Woman's milk,	1·0203‡
Mare's milk,	1·0546
Ass's milk,	1·0355
Goat's milk,	1·0341
Sheep's milk,	1·0409
Cow's milk,	1·0324
Clarified whey of cow's milk,	1·0193

Lassaigne examined the specific gravity of the milk at various distances before and after parturition, and states the results as follows:

42 days before parturition,	1·063
32,	1·062
21,	1·064
11,	1·040
Just after parturition,	1·039
4 days after,	1·035
6,	1·033
20,	1·040
21,	1·037
30,	10·38

The temperature at which these specific gravities were taken was usually about 46°. The cow during the whole time was fed upon the same kind of food, namely, beet-root, hay, and straw. We see that the specific gravity of the milk before parturition is higher than after it. These specific gravities are all higher than cow's milk, according to the statement of Brisson.

The first milk, or the milk which is given by the animal just after parturition, is called *colostrum*. In Scotland it goes by the

* Jour. de Phys. xxxvii. 362.

† Lavoisier's Traité Elementaire de Chimie, ii. 587.

‡ Henri and Chevalier say that it varies from 1·020 to 1·025. See Jour. de Pharm. xxv. 403.

name of *beist.* The same term, I believe, is applied to it in England.

When milk is allowed to remain for some time at rest there collects on its surface a thick unctuous, yellowish-coloured substance, known by the name of *cream.*

After the cream has separated, the milk which remains is much thinner than before, and has a bluish white colour. If it be heated to 100° and a little *rennet* (water digested with the inner coat of a calf's stomach and preserved with salt,) be poured into it, coagulation ensues. If the coagulum be broken the milk soon separates into two distinct substances; a solid white part known by the name of *curd,* and a fluid portion called whey. Thus milk is easily separated into three distinct substances, namely, *cream, curd,* and *whey.*

1. Cream is a semiliquid of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In three or four days it becomes so thick that the vessel containing it may be inverted without risking any loss. In eight or ten days more its surface is covered over with mucors and byssi, and it has no longer the flavour of cream but of very fat cheese.* In this state it constitutes what in this country is called *cream cheese.*

The quantity of cream yielded by milk varies not only in different animals, but in the same animal at different times. The following table shows the ratio between the bulks of cream and whey from the same cow, (fed on beet-root, hay, and straw,) at different periods before and after parturition, as determined by Lassaigne:†

	Volume of cream.	Volume of whey.	Water per cent.
42 days before parturition,	200	800	78·4
32 ditto,	200	800	78·2
21 ditto,	200	800	78·1
11 ditto,	200	800	78·8
Just after parturition,	200	800	78·2
4 days after ditto,	200	800	79·8
6 ditto,	188	812	82·0
20 ditto,	78	922	89·0
21 ditto,	59	941	88·0
30 ditto,	64	936	90·0

* Jour. de Phys. xxxvii. 372.

† Ann. de Chim. et de Phys. xlix. 35.

In a third column is inserted the weight of water contained in 100 parts of the respective milks.

Cream consists of a peculiar oily matter mixed with curd and whey, and the substances held in solution in the whey. When agitated for some time it separates into two portions, namely, a solid yellow substance called *butter*, and a liquid portion containing the greatest part of the curd and whey. This liquid is called *butter-milk.* The process itself is called *churning.*

The formation of butter goes on equally well whether the access of air be admitted or precluded. Macaire Princep has ascertained by experiment, that no oxygen is absorbed from the atmosphere during the process of churning. This indeed has long before been shown by Young* and by Thenard.†

In some cases it is said that there is an extrication of gas during the churning of butter, and it has been inferred that this gas is carbonic acid. But the fact has not been established in a satisfactory manner. Dr Young affirms, that during churning there is an increase of temperature amounting to 4 degrees.

Cream, according to the analysis of Berzelius, consists of,

Butter,	4·5
Curd,	3·5
Whey,	92·0
	100·0

but it varies so much in the proportion of its constituents that such analyses are of very little value.

The appearance and characters of butter are so universally known that it is needless to describe it. In its usual state it contains about $\frac{1}{6}$th of its weight of substances contained in butter-milk. To separate the butter from these substances it is to be put into a cylindrical glass, and raised to a temperature which must not be higher than 140°. The butter melts and swims upon the surface under the form of an oil, while the butter-milk is collected in the lower part of the vessel. When the butter oil has become clear it is to be poured into another vessel containing water heated to 104°, with which it is to be well-agitated, in order to separate every thing from it that is soluble in that liquid. When the mixture is left at rest the butter-oil collects on the surface, and when the water cools concretes into solid butter.

* Young de Lacte, p. 15. † Nicholson's Journal, xii. 218.

Thus purified butter is a white solid substance like tallow. Its yellow colour, when it has it, is owing to the food on which the cow was fed. According to Chevreul, melted butter may be cooled down to 80° before it congeals. The temperature then suddenly rises to 90°, and continues at that point till the solidification is completed.*

100 parts of alcohol of 0.822 dissolves 3·46 of butter. Butter is very easily saponified, requiring only 8 parts of potash ley to saponify 20 parts of it. 100 parts of cow's milk butter when thus saponified furnish 88·5 parts of fixed solid oily acids. This acid matter contains 11·85 of glycerin, a little stearic acid, and three volatile oily acids.†

Butter is composed of three kinds of fatty matter, namely, stearin, elain, and a fatty matter from which the three volatile oily acids are formed. To this last substance Chevreul, to whom we owe all the facts here stated, has given the name of *butyrin*. The relative proportions of these three fatty matters may vary according to circumstances. This is the reason why butter varies so much in its degree of consistence. Braconnot obtained by expression between 40 and 65 per cent. of stearin.‡ According to Chevreul, who separated it by crystallization from its solution in alcohol, it is crystalline, and whiter and more brilliant than stearin from ox tallow. It melts at 135°. 5 according to Braconnot. According to Chevreul, it melts at 111°, and 100 parts of alcohol of 0·822 dissolve only 1·45 of this stearin. 100 parts of it, when saponified, gave 94·5 of fatty acids fusible at 111°, and 7·2 of glycerin.

The elain of butter cannot be completely freed from butyrin, nor the butyrin from elain. Chevreul employed the following method to separate them: Purified butter was kept for a long time between 61° and 66° of temperature. At that temperature the elain and butyrin are liquid, while the solid stearin unites together by degrees, so that the liquid portion may be decanted off. This liquid portion is an oil having the specific gravity of 0·922 at 66°. 100 parts of boiling alcohol of 0·822 dissolve 6 parts of it. Upon this oil its own bulk of absolute alcohol was poured, and the mixture was left for twenty-four hours, being frequently agitated during that time, and the temperature was

* Chevreul sur les Corps Gras, p. 273. † Ibid.

‡ Ann. de Chim. xciii. 227.

66°. The alcohol being decanted off and distilled over the water-bath, left an oil which had an acid reaction, and the smell of butter. This oil was butyrin, mixed with a little elain. The acid reaction was owing to the property which alcohol has of partially decomposing the butyrin and developing a portion of the volatile acids, which it furnishes. They may be removed by digesting the butyrin with a mixture of water and magnesia. A salt of magnesia soluble in water is formed, and the butyrin becomes neutral.

Butyrin in this state is an oil, sometimes yellow, sometimes colourless. It has the taste and smell of butter, and becomes solid when cooled down to 32°. It is miscible in all proportions with boiling alcohol of 0·822. According to Chevreul, a mixture of 2 parts butyrin and 10 parts alcohol becomes muddy on cooling, while a mixture of 12 parts butyrin and 10 parts alcohol retains its transparency. The alcoholic solution becomes always acid, and the more so the longer the digestion continues. Butyrin is easily saponified. The fatty acids evolved by this process begin to solidify at 90°, but do not become quite solid till cooled down to 63°.

When the elain from butter is digested for a long time in absolute alcohol, the butyrin dissolved becomes more and more charged with elain as the process advances. If we digest it three times successively with twice its weight of absolute alcohol, the remaining elain which separates from the last portion of alcohol as it cools is as free from butyrin as it can be made by this process. It is not the least acid while the alcoholic solution reddens litmus. The specific gravity of this elain is 0·92 at 66°. Alcohol of 0·822 dissolves only four-fifths of a per cent. of it.

These three constituents of butter, namely, stearin, elain, and butyrin, are all analogous to salts, being combinations of certain oily acids and glycerin.

When butter is saponified by means of potash, or rather when the liquid portion of butter is treated in this way, and the soap is afterwards decomposed by adding a quantity of tartaric acid sufficient to convert the potash into bitartrate, the oily acids are disengaged. The fatty acids are now washed with water, and the water is distilled. The three peculiar acids of butter pass over with the water into the receiver. These acids are the *butyric*, the *caproic*, and the *capric*. An account of these acids

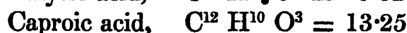
and of the method of separating them from each other, has been given in a preceding volume of this work.*

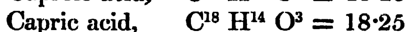
The composition of these three acids, according to the analysis of Chevreul, is as follows:

	Butyric.	Caproic.	Capric.
Carbon,	62·82	68·33	74·00
Hydrogen,	7·01	9·00	9·75
Oxygen,	30·17	22·67	16·25
	100·00	100·00	100·00

From the experiments of Chevreul it would appear that the atomic weight of butyric acid is 9·625, that of caproic acid 13·25, and that of capric acid 18·25. Hence the constituents of these acids should be,


Butyric acid, $C^8\ H^5\ O^3 = 9{\cdot}625$


Caproic acid, $C^{12}\ H^{10}\ O^3 = 13{\cdot}25$


Capric acid, $C^{18}\ H^{14}\ O^3 = 18{\cdot}25$

But new and careful analyses would be necessary before we could consider these numbers as established.

2. When milk freed from cream is heated to 110°, or a little higher, and mixed with a little *rennet*, it coagulates and gradually separates into a solid white matter called *curd*, and a liquid portion distinguished by the name of *whey*.

Curd when in a state of purity is distinguished by the name of *casein*. The mode of procuring it in a state of purity and its properties have been given in a preceding chapter of this volume. Casein has many properties in common with the albumen of blood, and like albumen may be obtained in two states, namely, uncoagulated, when it is soluble in water, and coagulated when it is insoluble in that liquid. It is precipitated from its aqueous solution by acetic acid, which is not the case with albumen. It is coagulated by a boiling heat, but slowly; separating in films which collect upon the surface of the liquid.

Coagulated casein subjected to pressure to free it from the whey constitutes cheese. If cheese consist of nothing but casein, it has a bluish white colour, is very hard, almost like horn, and is quite insipid. Good cheese is always made from milk still retaining its cream, and in Stilton, which is one of the richest of the English cheeses, the milk is not only allowed to retain its natural quantity of cream, but an additional quantity is added.

* See Chemistry of Inorganic Bodies, ii. 132.

It is impossible to state the proportion of casein which exists in milk, because it varies so much, not only in the milk of different animals, but also in that of the same animal at different times. According to Berzelius 100 parts of skimmed-milk which he analyzed contained 2·8 of casein.

Lassaigne made a curious remark respecting the milk of a cow, which he examined at ten different periods; four of these before parturition and six after it. The milk examined during the first three of these periods, namely, forty-two days, thirty-two days, and twenty-one days before parturition, contained no casein at all, but in place of it albumen. The milks examined eleven days before and just after parturition contained both albumen and casein; the milks examined four days, six days, twenty days, twenty-one days, and thirty days after parturition, contained casein and no albumen.* It would have been of importance had Lassaigne informed us of the method which he followed to distinguish casein from albumen, and to separate them from each other when they existed together in milk.

3. Whey, after being filtered to separate a quantity of curd, which usually floats through it, is a thin pellucid fluid of a yellowish green colour and an agreeable and sweetish taste, in which the flavour of milk may be distinguished. Almost the whole curd may be separated by keeping the whey for some time at a boiling temperature. A thick white scum gathers on the surface, known in Scotland by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being left at rest for some hours to give the remainder of the curd time to separate, is quite transparent, and much less coloured than before. It still retains its sweet taste, but much of the milky flavour is dissipated. If it be now evaporated over the steam bath it deposits a number of crystals of *sugar of milk*. Towards the end of the evaporation some crystals of chloride of potassium and some of common salt, make their appearance.† According to Scheele it contains also a little phosphate of lime, which may be precipitated by ammonia.‡

Schwarz found that 1000 parts of cow's milk left 3·697 of ashes, composed of

* Ann. de Chim. et de Phys. xlix. 35.
† Parmentier, Jour. de Phys. xxxvii. 417.
‡ Scheele's Essays, ii. 61.

Phosphate of lime,	1·805
Phosphate of magnesia,	0·170
Phosphate of iron,	0·032
Phosphate of soda,	0·225
Chloride of potassium,	1·350
Soda, combined with lactic acid,	0·115
	3·697*

Lassaigne observed that milk from the cow forty-two days, thirty-two days, and twenty-one days before parturition contained no sugar of milk and no lactic acid, but a sensible quantity of uncombined soda. In short, it bore a close resemblance to the albumen of blood. While milk from the same cow eleven days before parturition and always after it, contained free lactic acid and sugar of milk but no free soda.† It would appear from this and other observations of Lassaigne already noticed, that the milk of the cow is at first very similar to the serum of blood, and that the casein, sugar of milk, and lactic acid, to which it owes much of its distinguishing characters, begins first to make their appearance in it about eleven days before parturition.

The experiments of Fourcroy and Vauquelin, Thenard, Bouillon Lagrange, and Berzelius, have added considerably to our knowledge of the constituents of whey. The sugar of milk constitutes at an average about 3·5 per cent. of the whey; while the saline ingredients do not exceed 0·22 or two-ninths of a per cent. The water of course constitutes about 96·3 in the hundred parts. The saline contents of milk are, chloride of potassium, chloride of sodium, phosphate of lime, of magnesia, and a trace of phosphate of iron, acetate of potash, lactate of potash, lactic acid, and a trace of lactate of iron.

The *colostrum*, or beist milk of the cow, has a pretty deep-yellow colour with a tint of green. It contains a much greater proportion of *ricottin*, and a smaller of *casein* than milk in its ordinary state, and about six days after parturition elapse before the milk contains the normal quantity of these two substances. The colostrum when churned gives a very yellow butter which, when heated, emits a smell similar to that of the white of egg. From the observations of Parmentier and Deyeux, it would appear that

* Schweigger's Jour. viii. 271. † Ann. de Chim. et de Phys. xlix. 35.

the cream does not separate from the colostrum so easily as from ordinary milk. For after having removed the cream, a new portion gradually collected on the surface of the milk. Butter made from this second cream was not so yellow as that from the first. When the colostrum is heated it coagulates like albumen.

The colostrum of the cow, the ass, and goat was analyzed by Henri and Chevalier.* The result was as follows:

	Cow.	Ass.	Goat.
Casein,	150·7	116·0	245
Mucus,	20·0	7·0	30
Sugar of milk,	trace.	43·0	32
Butter,	26·0	5·6	52
Water,	803·3	828·4	641
	1000·0	1000·0	1000

The opinion of medical men is, that the colostrum possesses purgative properties, and that it is intended to free the bowels of the new-born animal from the meconium with which they are partly filled at the time of birth.

Milk is one of the few animal substances which may be made to undergo the vinous fermentation, and to afford a liquid resembling beer, from which alcohol may be separated by distillation. For this property it is indebted to the *sugar of milk* which it contains, and which, like common sugar and sugar of grapes, is susceptible of being decomposed into alcohol and carbonic acid. The method of fermenting milk appears to have been discovered by the Tartars, who obtain all their spirituous liquors from mare's milk. The process followed by them is very simple: The milk is allowed to become sour, it is then raised to the requisite temperature. In summer the fermentation begins immediately, and in twenty-four hours the liquid is converted into an intoxicating liquor, to which the Tartars give the name of *koumiss* or *kumysz*. In winter the process lasts two or three days, and the koumiss may be kept for two or three months without losing any of its good qualities. It has then an acid, and at the same time a sweet taste, and possesses intoxicating qualities.

An account of the preparation and medical uses of koumiss was published by Dr Guthrie in the second volume of the Transactions of the Royal Society of Edinburgh. Indeed some ac-

* Jour. de Pharm. xxv. 348.

count of it, with a receipt for making it, was inserted by Dr Grieve in the first volume of these Transactions. A little very sour milk is added to the mare's milk that is to be converted into koumiss, and the whole milk must be frequently and thoroughly agitated several times during the process. The koumiss must always be well agitated just before it is to be used. The Tartars consider this liquid as highly nutritive and medicinal. There is an elaborate history of this liquid, together with a set of experiments on the fermentation of sugar of milk, by M. Schill, in the thirty-first volume of Liebig's *Annalen der Pharmacie*, (page 152.) Many chemists had failed in their attempts to ferment milk and obtain alcohol from it. Schill, however, succeeded. I have been informed by the late Sir John Sinclair that koumiss is made both in Orkney and Shetland nearly in the same way as in Tartary. Of course, they will use cow's milk in these islands instead of mare's milk.

From the experiments of numerous chemists it had been concluded that sugar of milk is incapable of fermenting, and of course of yielding alcohol. But Scheele had long ago observed that milk ferments, and gives out a great deal of carbonic acid gas.* And Schill found by experiment, that 100 parts of sugar of milk by fermentation may be made to yield 36·101 of absolute alcohol.†

A set of experiments was made by MM. Boussingault and Le Bel, to determine the effect of various kinds of food upon the quantity and quality of the milk given by cows.‡ They have not given satisfactory results. Because the quantity of milk diminishes in proportion as the time after calving increases. They deserve a place, however, as giving the quantity and quality of the milk of the same cow during a period of 302 days.

* Scheele's Opuscula, ii. 66. † Annalen der Pharm. xxxi. 171.
‡ Ann. de Chim. et de Phys. lxxi. 65.

Composition of the milk.

Days since calving.	Quant. of milk in imp. gallons in 24 hours.	Solid matter in 100 milk.	Food equivalent to 33 lbs. of hay.	Casein.	Butter.	Sugar of milk.	Earthy salts.	Water.
			FIRST SERIES.					
1	1·1	21·6	potatoes, hay,	15·1	2·6	3·6	0·3	78·4
13	1·65	—	ditto,	—	—	—	—	—
24	2·33	11·2	hay, clover,	3·0	3·5	4·5	0.2	88·8
35	2·64	13·1	clover,	3·1	5·6	4·2	0·3	86 9
200	1·23	12·3	hay,	3·0	4·5	[illegible]·7	0·1	87·7
207	1·32	12·4	turnips,	3·0	4·2	5·0	0·2	87·6
215	1·23	12·9	beet,	3·4	[illegible]·0	5·3	0·2	87·1
229	1·09	13·5	potatoes,	3·4	4·0	5·9	0·2	86·5
240	0·78	—	hay,	—	—	—	—	—
270	0·75	—	potatoes,	—	—	—	—	—
290	0·77	12·5	Jerusalem artichoke,	3·3	3·5	5·5	0·2	87·5
302	0·62	13·2	hay and oil-cake,	3·4	3·6	6·0	0·2	86·8
			SECOND SERIES.					
176	2·05	13·5	potatoes, hay,	3·3	4·8	5·1	0·3	86·5
182	1·96	12·8	hay, clover,	4·0	4·5	4·0	0·3	87·2
193	2·16	11·2	clover,	4·0	2·2	4·7	0·3	88·8
20[illegible]	1·72	12·6	clover in blossom,	3·7	3·5	5·2	0·2	87·4

The most remarkable circumstance in this table is the small quantity of milk given by the French cows subjected to experiment. It is no uncommon thing for a good Ayrshire cow to give 4½ imperial gallons in 24 hours. The greatest quantity in the above table is 2·64 gallons: not much more than the half of 4½ gallons.

The milk of the other mammalia, so far as has been examined, consists nearly of the same ingredients as cow's milk; but there is a great difference in their proportions.

1. Woman's milk is thinner, more transparent, and much sweeter than cow's milk. When left at rest a cream collects on the surface, which has a whiter colour, and is more transparent than cow's milk cream. The creamed milk is thin, and has rather the appearance of whey with a bluish white colour, than of skimmed milk.

It was stated by Parmentier and Deyeux, that this cream did not yield butter. But Pleischl showed in 1821, that this was a mistake, and that butter might be obtained from woman's milk as well as from that of the cow.* Indeed Stipriaan, Luiscius, and

* Schweigger's Jour. xxxii. 124.

Dr Bondt, proved as early as 1787, that butter could be obtained from woman's milk.*

None of the methods by which cow's milk is coagulated succeed in producing the coagulation of woman's milk.† Meggenhoffer found that while cold, neither muriatic acid, acetic acid, acetate of lead, perchloride of iron, sulphate of copper, nor corrosive sublimate caused it to coagulate; but coagulation was produced if the milk was warm. Sometimes, though but seldom, alcohol caused it to coagulate. The same remark applies to nitrate of silver. In 20 trials, sulphate of iron caused the coagulation of about one-half. Protochloride of tin, acetate of lead, protonitrate of mercury, and tincture of nut-galls had a similar action to nitrate of silver. All these specimens of woman's milk reddened litmus-paper.‡

Woman's milk, according to Meggenhoffer, contains from 11 to 12½ per cent. of solid matter, and the quantity is greater a considerable time after parturition than soon after it. By digesting the solid matter of milk in alcohol Meggenhoffer obtained a butter which melted at 88°; and the stearin deposited from the alcohol as it cooled melted at 95°. This butter agrees, therefore, with that from cow's milk.

The characteristic property of woman's milk is, that the casein forms soluble compounds with the acids, so that we cannot throw it down by their means. But this casein may be coagulated by rennet. It does not concrete into a mass as in cow's milk, but appears in isolated flocks. The mean quantity of casein in this milk is between 2¼ and 3 per cent. The following table exhibits the result of the analysis by Meggenhoffer, of three different specimens of milk from different women:

	1.	2.	3.
Alcoholic extract, with butter, lactic acid, and lactates, common salt, and a little sugar of milk,	9·13	8·81	17·12
Aqueous extracts, sugar of milk, and salts,	1·14	1·29	0·88
Casein, coagulated by rennet,	2·41	1·47	2·88
Water,	87·25	88·35	78·93
	99·93	99·92	99.81

* Crell's Annalen, 1794, 76. † Clarke, Irish Trans. ii. 175.
‡ Gmelin's Handbuch der Theor. Chimie, ii. 1402

Payen* has given the following results of the analysis of woman's milk from three several women:

	1.	2.	3.
Fat, melting at 75°, .	5·16	5·20	5·18
Sugar of milk, soluble salts with trace of animal matter, . .	7·62	7·93	7·86
Casein and insoluble salts, .	0·18	0·25	0·24
Water, ...	86·00	85·60	85·80†
	98·96	98·98	99·08
Solid matter in the milk, .	13·	13·4	13·3

The constituents of woman's milk in its normal state, according to the analysis of Henri and Chevalier are,

Casein, .	15·2
Butter, .	35·5
Sugar of milk,	65·0
Salts, .	4·5
Water, .	879·8
	1000·0‡

According to Schübler most of the casein in woman's milk is in the state of ricottin. But this remark does not quite accord with the experiments of Meggenhoffer.

According to the experiments of Schwarz, 1000 parts of woman's milk leave an ash when burnt, weighing 4·407 : and composed of,

Phosphate of lime, .	2·5
Phosphate of magnesia,	0·5
Phosphate of iron, .	0·007
Phosphate of soda, .	0·4
Chloride of potassium,	0·7
Soda combined with lactic acid,	0·3
	4·407§

2. *Ass's milk* has a strong resemblance to human milk. It has nearly the same colour, smell, and consistence. When at

* Jour. Chim. Med. iv. 118.

† It is obvious that most of the casein remained in solution, and was confounded with the sugar of milk, &c. obtained by evaporating the whey.

‡ Jour. de Pharm. xxv. 340. § Schweigger's Jour. viii. 271.

rest a cream collects on its surface: but by no means in such quantity as in woman's milk. This cream, by very long agitation, yields a butter which is always soft, white, and tasteless; and what is singular, readily mixes with the butter milk; but it may be again separated by agitation, while the vessel which contains it is plunged in cold water. Creamed ass's milk is thin, and has an agreeable sweetish taste. Alcohol and acids separate from it a little curd, which has but a small degree of consistence. The serum yields sugar of milk and chloride of calcium.*

According to the experiments of Stipriaan, Luiscius and Bondt, ass's milk yields at an average 2·9 per cent. of cream, 2·3 of casein, and 4·5 of sugar of milk. It undergoes very readily the vinous fermentation.† They found the specific gravity of ass's milk 1·023.

In 1836, M. Péligot published some interesting experiments on ass's milk. The object which he had in view was, if possible, to discover whether the medicinal properties ascribed to this milk might not be accounted for by some variation in its solid constituents from that of the milk of other animals.‡ Its specific gravity varies from 1·030 to 1·035, being nearly the same as that of cow's milk, yet it contains less solid matter. But cow's milk contains more cream, which counteracts the effect of its solid contents.

The mean composition of ass's milk, according to Peligot, is,

Solid matters,	9·53	Butter,	1·29
		Sugar of milk,	6·29
		Casein,	1·95
Water,	90·47		9·53
	100·		

It contains more sugar of milk than cow's milk, and to this he ascribes its medicinal properties.

It was found that the proportion of solid matter varied according to the food by which the ass was nourished. The following are the results:

1. An ass fed during a month on carrots yielded a milk composed of,

* Parmentier and Deyeux, Jour. de Phys. xxxvii. 423.

† Crell's Annalen, 1794, ii. 266.

‡ Ann. de Chim. et de Phys. lxii. 432.

Solid matters,	8·89	Butter, .	1·25
		Sugar of milk,	6·02
		Casein, .	1·62
Water, . .	91·11		8·89
	100·		

2. The same ass fed for a fortnight on beet-root. The milk gave,

Solid matters,	10·23	Butter, .	1·39
		Sugar, .	6·51
		Casein, .	2·33
Water, .	89·77		10·23
	1000·00		

3. The same ass fed for a month on pounded oats and dry lucerne gave a milk of,

Solid matters,	9·37	Butter, .	1·40
		Sugar, .	6·42
		Casein, .	1·55
Water, .	90·63		9·37
	100·		

4. The same ass fed for a fortnight on potatoes yielded a milk composed of,

Solid matters, .	9·29	Butter, .	1·39
		Sugar, .	6·70
		Casein, .	1·20
Water, .	90·71		9·29

From these experiments it would seem that the most nourishing food was beet-root, the next oats and lucerne, next potatoes, and carrot the least nourishing of all. The quantity of milk was proportional to the nourishment yielded by the food.

Beet-root gave .	1·5	kylogrammes of milk.
Oats and lucerne,	1·5	
Potatoes, . .	1·28	
Carrots, . .	1·0	

The longer the milk remains in the udder of the ass after milking before it be milked again, the less solid matter does the milk contain, as will appear from the following table:

	In 1½ hour.	After 6 hours.	After 24 hours.
Butter,	1·55	1·40	1·23
Sugar,	6·65	6·40	6·33
Casein,	3·46	1·55	1·01
Solid matters,	11·66	9·37	8·57
Water,	88·34	90·63	91·43
	100·	100·	100·

When milk is examined at the beginning, middle, and end of the same milking, the last drawn milk is the richest. This will appear from the following table:

	First drawn.	Middle.	End.
Butter,	0·96	1·02	1·52
Sugar,	6·50	6·48	6·45
Casein,	1·76	1·95	2·95
Solid matters,	9·22	10·45	10·94
Water,	90·78	89·55	89·66
	100·	100·	100·

M. Peligot found that when iodide of potassium, common salt, or bicarbonate of soda was mixed with the food of the ass, the presence of these substances in the milk became sensible.

Henri and Chevalier state the constituents of ass's milk in its normal state to be,

Casein,	18·2
Butter,	1·1
Sugar of milk,	60·8
Salts,	3·4
Water,	916·5
	1000·0 *

Ass's milk, after the animal had undergone great fatigue, yielded,

* Jour. de Pharm. xxv. 340.

Casein, .	11·2
Butter, .	1·3
Sugar of milk,	59·0
Salts, .	6·1
Water, .	922·4
	1000·0 *

3. *Mare's milk* is thinner than that of the cow, but scarcely so thin as woman's milk. Parmentier and Deyeux did not succeed in obtaining butter from it by churning. But we know from Herodotus that the ancient Scythians made butter from that milk, several centuries before the commencement of the Christian era. Its specific gravity is from 1·045 to 1·035, as determined by Stipriaan, Luiscius, and D. Bondt.† The creamed milk coagulates just as cow's milk, but the curd is not so abundant. The whey contains sugar of milk, sulphate of lime, and chloride of calcium.‡ It readily ferments, and is converted by the Tartars into koumiss.

According to Luiscius and Bondt, mare's milk contains

Casein, .	16·2
Butter, .	trace.
Sugar, .	87·5
Salts and water,	896·3
	1000·0§

M. Henri, Senior, in 1830 examined a little milk from the udder of a foal only four days old. Its specific gravity was 1·002. It threw up no cream; but when heated, was concreted and divided into casein and serum. It yielded,

Fatty matter, .	1·
Casein, . .	0·5
Serum, . . .	28·5
	30·0‖

4. *Goat's milk*, if we except its consistency, which is greater, does not differ much from cow's milk. It throws up abundance of cream, from which butter is easily extracted. The creamed

* Jour. de Pharm. xxv. p. 346. † Ibid. p. 347.

‡ Parmentier and Deyeux; Jour. de Phys. xxxvii. 428.

§ Crell's Annalen, 1794, ii. 352. ‖ Jour. de Pharmacie, xvi. 418.

milk coagulates just as cow's milk does; but yields a greater quantity of curd. From the whey was extracted sugar of milk, chloride of calcium, and common salt.*

Payen extracted from goat's milk,

Butter,	4·08
Casein and insoluble salts,	4·52
Sugar of milk and soluble salts,	5·86
Water,	85·50
	99·96 †

Stipriaan, Luiscius, and Bondt obtained,

Cream 7·5 per cent., yielding of butter 4·56 per cent.; 9·12 per cent. of casein, and 4·38 of sugar of milk. ‡

Henri and Chevalier state the constituents of normal goat's milk to be,

Casein,	40·2
Butter,	33·2
Sugar of milk,	52·8
Salts,	5·8
Water,	868·0
	1000·0§

5. *Ewe's milk* resembles very closely that of the cow. Its specific gravity was found by Stipriaan, Luiscius, and Bondt, to be 1·035. Its cream is rather more abundant than from cow's milk, and it yields a butter which never acquires the consistence of common butter. Its curd has a fat and viscid appearance.

Normal ewe milk, according to the analysis of Henri and Chevalier, is composed of,

Casein,	45·0
Butter,	42·0
Sugar of milk,	50·0
Salts,	6·8
Water,	856·2
	1000·0‖

* Parmentier and Deyeux, Jour. de Phys. xxxvii. 425.
† Jour. Chim. Med. iv. 118.
‡ Crell's Annalen, 1794, ii. 252.
§ Jour. de Pharm. xxv. 340.
‖ Jour. de Pharm. xxv. 340.

CHAPTER X.

OF THE EGGS OF FOWLS.

THE *eggs* of all birds, so far as they have been examined, bear a striking resemblance to each other. They consist of four parts, 1. The *shell*, which is white in the eggs of the common fowl, and of many other birds; but it is often coloured or spotted of various colours, so as to give it a beautiful appearance. 2. The *membrana putaminis*, a thin translucent pellicle immediately within the shell. At the great end of the egg this membrane is detached from the shell, leaving a certain distance between them, which is filled with air. 3. The *white* or *albumen*, a glairy liquid consisting of albumen dissolved in water, and contained, like the vitreous humour of the eye, in an extremely thin membrane divided into cells. 4. The *yolk*, a thick and almost solid yellow matter, inclosed in a peculiar membrane. This membrane, by two ligaments called *chalazæ*, is tied to the membrane of the albumen, and thus the yolk is kept in the centre of the egg.

1. The shell of the common fowl was analyzed by Vauquelin* and Merat Guilot.† But both of these chemists seem to have overrated the quantity of animal matter which it contains. According to Dr Prout's analyses, which seem to have been conducted with scrupulous attention to accuracy, its constituents are,

Carbonate of lime with a little carbonate of magnesia,	97
Phosphate of lime and magnesia,	1
Animal matter,	2
	100‡

2. If we suppose the weight of the whole egg to be 1000 grains, the average weight of the *membrana putaminis* will be 2·35 grains.§ This membrane has not been subjected to analysis. According to Hatchett it consists of coagulated albumen.

* Ann. de Chim. lxxxi. 304.
† Ann de Chim. xxxiv. 71.
‡ Phil. Trans. 1822, p. 381.
§ Prout, Ibid.

It is stated by Berzelius, I know not on what authority, to be easily converted into gelatin when boiled in water.

3. The glairy liquid called the *white* coagulates into a firm white solid when heated to 159°. Hence it is a solution of albumen in water. This aqueous solution when evaporated to dryness leaves about 14 per cent. of albumen. Dr. Bostock has shown that it contains also a little mucus.* According to him the mean constitution of white of egg is:

Water,	80
Albumen,	15·5
Mucus,	4·5
	100*

Dr Prout determined by combustion the quantity of fixed constituents which albumen contains. If we suppose the original weight of the egg to have been 1000 grains, the following table shows the weight of the fixed constituents in three different eggs:

	No. 1.	No. 2. Grains.	No. 3.
Sulphuric acid,	0·29	0·15	0·18
Phosphoric acid,	0·45	0·46	0·48
Chlorine,	0·94	0.93	0·87
Potash, soda, and carbonates of do.	2·92	2·93	2·72
Lime, magnesia, and carbonates of do.	0·30	0·25	0·32
	4·90	4·72	4·57

It was long uncertain whether the sulphur and phosphorus exist in the white of egg in the state of sulphuric and phosphoric acids, or in that of sulphur and phosphorus. What renders the second of these suppositions probable is, that the acids are too small in quantity to neutralize the bases; and it is well-known that the white of egg has an alkaline reaction. The existence of these bodies in the state of sulphur and phosphorus has been at last proved by M. Mulder, as has been noticed when treating of albumen in a preceding chapter of this volume.

4. The yolk consists of water, albumen, and fixed oil, mixed so as to constitute an emulsion. It contains also a colouring matter, for which it is indebted for its yellow colour. Dr Prout ana-

* Nicholson's Jour. xi. 246, and xiv. 142.

lyzed it in the following manner: An egg was boiled hard in distilled water, and the yolk in that state was found to weigh 316·5 grains. It was then partially dried by exposure to the air for several weeks, and to remove the remainder of the water, it was reduced to powder and dried in a heat somewhat more than 212°. The total loss of weight was 170·2 grains, which was considered as owing to the escape of water. The residue was digested repeatedly in alcohol of 0·807 till that liquid came off colourless. What remained was a white powder possessing many of the properties of coagulated albumen, but differing from that principle by the large quantity of phosphorus which it contained in some unknown state of combination. The alcoholic solution was of a deep-yellow colour, and deposited crystals of a sebaceous matter, and a portion of yellow semifluid oil. On distilling off the alcohol the oil was obtained in a separate state. On cooling, it became nearly solid, and weighed 91 grains. The albumen weighed 55·3 grains. Hence the yolk consisted of,

	Grains.	
Water,	170·2	or 53·78
Albumen,	55·3	or 17·47
Yellow oil,	91·0	or 28·75
	316·5	100·00

But he found these proportions to vary a little in different eggs.*

According to Planche, 1000 parts of yolk of egg furnish at an average 180 parts of oil. This oil consists of stearin and elain in the following proportions:

Stearin,	10
Elain,	90
	100

The stearin is white, solid, and does not stain paper like oil. 100 parts of boiling alcohol, of the specific gravity 0·805, dissolve 10·46 parts of this stearin. He found the stearin from the fat of fowls of a fine white colour, and 100 parts of alcohol of 0·805 dissolved 10·09 parts of it, showing it to agree very nearly with the stearin from the yolk of egg.†

The elain from the yolk possesses the characters of a fixed oil, but has not hitherto been subjected to a chemical investigation.

* Phil. Trans. 1822, p. 387. † Jour. de Pharmacie, ix. 2.

Chevreul has found two colouring matters in the yolk, the one *red*, and the other *yellow*.

Lecanu, besides the stearin and elain, extracted from the yolk of egg a crystalline matter which melted at 293°, and which he considered as of the same nature with cholesterin from the brain.*

Dr Prout† determined the quantity of fixed constituents of dried yolk of egg by incineration. He pounded the yolk with bicarbonate of potash in a mortar, and then heated it in a covered platinum crucible till flame ceased to escape from a small hole in the lid. The contents when cold were removed from the crucible and again pounded with nitre. The mixture was now introduced by a little at a time till the whole was burnt. To the residuum water was added, which dissolved every thing but the earthy phosphates. From the aqueous solution everything was obtained except the alkaline matter contained in the yolk. To obtain these a new portion of the yolk was treated as before, substituting lime and nitrate of lime for bicarbonate of potash and nitre. The following table exhibits the quantity of fixed matter obtained in this way from three different yolks :

	No. 1.	No. 2.	No. 3.
Sulphuric acid, . .	0·21	0·06	0·19
Phosphoric acid, ...	3·56	3·50	4·00
Chlorine, ...	0·39	0·28	0·44
Potash, soda, and carbonates of do.	0·50	0·27	0·51
Lime, magnesia, and carbonates of do.	0·68	0·61	0·67
	5·34	4·72	5·81

Whether the sulphur and phosphorus exist in the yolk in the state of acids, or as sulphur and phosphorus is not known, though the last supposition is most probable. When we compare the fixed constituents of the *white* and yolk, we cannot avoid being struck with the difference. The *white* contains a much greater quantity of fixed alkalies than of any other fixed constituent; while in the yolk the most abundant constituent is phosphoric acid, which amounts to from 3·5 to 4 grains, or, if we suppose it to exist as phosphorus, it varies in a single yolk from 1·55 to 1·77 grains.

The specific gravity of a new laid egg varies from 1·080 to

* Berzelius, Traité de Chimie, ix. 573. † Phil. Trans. 1822, p. 386.

1·090. When kept, eggs rapidly lose weight and become specifically lighter than water. This is owing to the diminution of bulk in the contents of the egg; the consequence of which is that a portion of the inside of the egg comes to be filled with air. Dr Prout kept an egg two years, and found that it lost weight daily at the average rate of 0·744 grains. The original weight was 907·5 grains, and after two years exposure to the atmosphere it weighed only 363·2 grains. The total loss amounted to 544·3 grains, or considerably more than half the original weight. The loss in summer was somewhat greater than in winter, owing, no doubt, to the difference of temperature. Had the original weight of the egg been 1000, then after two years exposure to the atmosphere it would be reduced to 400.

The relative weights of the shell and lining membrane, albumen, and yolk are very different. Supposing the original weight of the egg to have been 1000, Dr Prout found the relative proportions in ten different eggs as follows:—

Shell and membrane. Grains.	Albumen.	Yolk.
104·8	516·6	378·6
110·8	608·5	280·7
116·7	626·3	257·0
89·0	643·2	267·8
117·6	575·0	307·4
119·5	575·3	305·2
98·0	636·6	265·4
107·1	596·0	296·9
118·3	624·0	257·7
87·5	640·0	272·5
106·9	604·2	288·9 average.

When an egg is boiled in water it loses weight, particularly if it be removed from the water when boiling, and be permitted to cool in the open air. The water will be found to contain a portion of the saline constituents of the egg. The loss of weight from boiling is not constant, varying from twenty to thirty grains, supposing the original weight of the egg to have been 1000 grains. The quantity of saline matter obtained by evaporating the distilled water in which an egg was boiled, amounts at an average to 0·32 grains. It is strongly alkaline, and yields traces of ani-

mal matter, sulphuric acid, phosphoric acid, chlorine, and alkali, lime and magnesia, and carbonates of lime and magnesia; in fact, of all the fixed principles found to exist in the egg. But the carbonate of lime is most abundant, and is obtained by evaporation in the form of a white powder.*

It is well known that when the egg is kept at a temperature of about 100° by the warmth of the mother, or by any other artificial means for three weeks, a chicken is formed in it, which, at the end of that period, breaks the shell. Dr Prout made a number of experiments to determine the changes which take place in the constituents of the egg during the period of incubation. † The following is a summary of these experiments:

If we suppose the original weight of the egg to be 1000 grains, it will be found that, after a week's incubation, the average loss is about fifty grains. The following table shows the amount of the various constituents of the egg on the eighth day of incubation in two different eggs:—

	No. 1. Grains.	No. 2. Grains.
Unchanged albumen,	232·8	247·1
Modified albumen,	179·8	275·2 (Modified albumen; Liquor amnii, &c.; Animal, together)
Liquor amnii, membranes, blood-vessels, &c.	97·0	
Animal,	22·0	
Yolk,	301·3	324·5
Shell and loss,	167·1	153·2
	1000·0	1000·0

As soon as the process of incubation has commenced the yolk becomes more fluid than usual; the liquor amnii increases, and that portion of the albumen occupying the upper and larger end of the egg begins to assume a peculiar aspect. When the egg is boiled it puts on an appearance somewhat resembling that of curds-and-whey. It has a yellow colour, and contains a portion of the oil of the yolk. Hence it would appear that a portion of the oil of the yolk must in some unknown way pass into that part of the albumen. It is this portion of the albumen which, in the preceding table, is distinguished by the name of *modified albumen.* The yolk at this period has become more

* Prout, Phil. Trans. 1822, p. 380. † Ibid. p. 388.

fluid, and appears larger and of a paler colour than natural, and from the preceding table would appear to have somewhat increased in weight. This would indicate a portion of the albumen added to it, and more than compensating the loss of oil.

The following tables exhibit the quantity of fixed constituents in these contents of the egg on the eighth day of incubation:—

No. 1.	Sulphuric acid. Grains.	Phos. acid. Grains.	Chlorine. Grains.	Potash, &c. Grains.	Lime, &c. Grains.
Unchanged albumen,	0·13	0·27	0·19	1·03	0·18
Modified albumen, liquor amnii, &c.	0·08	0·38	0·45	1·17	0·12
Yolk, ...	0·09	4·03	0·60	0·80	0·68
	0·30	4·68	1·24	3·00	0·98
No. 2.					
Unchanged albumen,	0·18	0·18	0·24	1·50	0·12
Modified albumen, liquor amnii, &c.	0·10	0·25	0·30	0·70	0·12
Yolk, ...	0·08	4·00	0·56	0·75	0·67
	0·36	4·43	1·10	2·95	0·91

From these tables it appears that, though the oily matter of the yolk has made its way to the albumen, very little of the phosphorus has been removed from it.

The following table shows the fixed constituents at the end of the tenth day of incubation:—

	Sulphuric acid. Grains.	Phos. acid. Grains.	Chlorine Grains.	Potash, soda, &c. Grains.	Lime, mag. &c. Grains.
Unchanged albumen,	0·27	0·14	0·24	1·13	0·12
Modified albumen, &c.	0·08	0·65	0·68	1·36	0·27
Yolk, . .	0·05	3·35	0·30	0·62	0·66
	0·40	4·14	1·22	3·11	1·05

At this period the quantity of phosphorus in the yolk is somewhat diminished and increased in the animal and its appendages. The chlorine and alkalies seem also to have diminished in the yolk.

At the end of the second week of incubation the egg has lost upon an average 130 grains, supposing its original weight to have been 1000 grains. The weight of its constituents in two different eggs are as follows:—

	No. 1. Grains.	No. 2. Grains.
Unchanged albumen,	175·5	208·0
Liquor amnii, &c.	273·5	218·2
Animal,	70·0	89·1
Yolk,	250·7	248·0
Shell and loss,	230·3	236·7
	1000·0	1000·0

At this period the animal has acquired a considerable size, while the albumen has diminished in a corresponding degree. The albumen has acquired a very firm consistence when coagulated by heat. The liquor amnii is more fluid, and the modified albumen has disappeared. The yolk has resumed its original size and consistence.

The following table shows the fixed constituents at this period in two different eggs:—

	Sulphuric acid. Grains.	Phos. acid. Grains.	Chlorine. Grains.	Potash, soda, &c. Grains.	Lime, magnesia, &c. Grains.
No. 1.					
Uunchanged albumen,	0·07	0·22	0·09	0·73	0·10
Liquor amnii, membranes, &c.	0·06	0·21	0·71	0·96	0 08
Animal,	0·06	0·23	0·09	0·46	0·27
Yolk,	0·30	3·34	0·16	0·68	0 69
	0·49	4·00	1·05	2·83	1·14
No. 2.					
Unchanged albumen,	0·11	0·19	0·23	0·97	0·09
Liquor amnii, membrane, &c.	0·03	0·20	0·70	1·07	0·08
Animal,	0·06	0·20	0·07	0·44	0·28
Yolk,	0·20	3·30	0·10	0·42	0·70
	0·40	3·93	1·10	2·90	1·15

An egg analyzed two days later, or on the seventeenth day of incubation, gave the following results:—

	Sulphuric acid. Grains.	Phos. acid. Grains.	Chlorine. Grain.	Potash, soda, &c. Grains.	Lime, magnesia, &c. Grains.
Liquor amnii, membranes, animal, &c.	0·34	1·70	0·68	2·40	1·10
Yolk,	0·10	2·50	0·30	0·56	0·75
	0·44	4·20	0·98	2·96	0·85

At this period ossification has made considerable progress

The yolk has parted with some of its phosphorus, which appears in other principles of the egg.

The following table shows the contents of the egg at the end of the third week, or at the full term of incubation in two different eggs:—

	No. 1. Grains.	No. 2. Grains.
Residuum of albumen, membranes, &c.	29·5	38·1
Animal,	555·1	553·6
Yolk,	167·7	151·3
Shell and loss,	247·7	257·0
	1000·0	1000·0

At this period all the important changes of incubation are completed. The albumen has disappeared or is reduced to a few dry membranes together with earthy matter. The yolk is considerably reduced in size, and is taken into the abdomen of the chick, while the animal has attained a weight nearly equal to the original weight of the albumen, together with that lost by the yolk, minus the total loss of weight sustained by the egg during incubation. The alkaline matters and chlorine have diminished in quantity, while the earthy matters have considerably increased.

The following table shows the fixed constituents in the contents of two eggs at the end of the period of incubation :—

	Sulphuric acid. Grains.	Phos. acid. Grains.	Chlorine. Grains.	Potash, &c. Grains.	Lime, Grains.
Residue of albumen, &c.	0·04	0·12	0·09	0·23	0·12
Animal,	0·44	3·02	0·55	2·26	2·58
Yolk,	0·04	1·06	0·03	0·06	1·26
	0·52	4·20	0·67	2·55	3·96
Residue of albumen, &c.	0·03	0·13	0·09	0·25	0·12
Animal,	0·21	2·71	0·68	2·12	2·60
Yolk,	0·02	1·25	0·06	0·03	1·10
	0·26	4·07	0·83	2·40	3·82

It follows, from these experiments, that during the last week of incubation the yolk loses most of its phosphorus, which is found in the animal converted into phosphoric acid, and combined with lime, constituting its bony skeleton. This lime does not exist in the recent egg, but is derived from some unknown source during the process of incubation.

Mr Hatchett made the curious remark that in the ova of those tribes of animals, the embryos of which have bones, there is a portion of oily matter, and in those ova whose embryos consist entirely of soft parts, there is none. In what way the oily matter contributes to the formation of bone, it is impossible, in the present state of our knowledge, even to conjecture. Nor can any source of the lime of the bones be pointed out except the shell. And it would be very difficult to determine whether the shell loses lime during the process of incubation.

CHAPTER XI.

OF THE ROE OF FISHES.

The *roe* of fishes is well-known as the ovarium of that tribe of animals. It consists of a congeries of very small eggs; the number of these in a single fish is remarkable. M. Petit found 342,244 in a carp of eighteen inches, and Leeuwenhoek states the number in a cod-fish to be 9,344,000. Now, as each of these is capable of producing a fish, we need not be surprised at the immense numbers which swarm in the ocean and rivers, notwithstanding the numerous enemies to which they are exposed.

The first set of experiments to determine the chemical nature of the roe of fishes was made by Vauquelin on that of the pike (*Esox lucius*) in 1817.* In 1823, M. Morin examined the roe of the common *trout* (*Salmo fario*), and the *carp* (*Cyprinus carpio*, Linn.†); and in 1827, M. Dulong d'Astafort published a chemical examination of the roe of the *barbel* (*Cyprinus barbus*, Linn.)‡

1. Vauquelin analyzed the roe of the fish in the following manner: Four pounds of it were washed with water, till everything soluble was taken up. The liquor being evaporated by the aplication of heat coagulated into a white flocky matter, which, when dried, was gray and brittle, soluble in caustic potash, and precipitated by infusion of nut-galls and by nitric acid in white flocks. It was albumen.

When a portion of the coagulum from aqueous solution was incinerated, it left a white alkaline ash, which consisted of car-

* Jour. de Pharmacie, iii. 385. † Ibid. ix. 203. ‡ Ibid. xiii. 521.

bonate of potash, phosphate of potash, common salt, and phosphate of lime.

The liquid, from which the coagulated albumen had precipitated, having been evaporated to dryness, left a yellowish-brown extract, which was alkaline, had a fish smell, and tasted strongly saline. It was insoluble in alcohol, but dissolved in water. Alcohol threw down from the aqueous solution brown flocks, which redissolved in water, and possessed the characters of gelatin. When burnt, it left an ash consisting chiefly of phosphate of magnesia, a little phosphate of lime, and carbonate of lime.

The alcohol, which precipitated the above substances, when evaporated, left a brown matter, having a saline and pungent taste, in which cubic crystals of chloride of potassium were formed. When triturated with potash, this substance gave out a strong smell of ammonia.

The roe of the pike formerly treated with water was now boiled in strong alcohol, and the boiling solution was passed through the filter. It was yellow, and became muddy when mixed with water or allowed to cool. When the alcohol was evaporated it left an oily matter, having an orange-colour, and the taste and smell of fish. It contained a notable quantity of phosphorus.

The roe thus exhausted by water and alcohol was burnt in a crucible. It left a charcoal difficult to incinerate, and which underwent a sort of imperfect fusion by the action of the fire. When digested in water it furnished an acid liquor precipitating lime and barytes water in white flocks, and oxalate of ammonia in powder. It therefore contained phosphoric acid and lime.

From this imperfect analysis it appears that the roe of the pike contains,

1. Much albumen.
2. An oil.
3. An animal matter, resembling gelatin.
4. Chlorides of potassium and sodium.
5. Sal-ammoniac.
6. Phosphates of potash, lime, and magnesia.
7. Sulphate of potash.
8. Phosphorus.

The analogy between the constituents of this roe and those of the eggs of common fowls is very remarkable.

2. M. Morin followed much the same plan as Vauquelin in analyzing the roe of the *common trout.*

He digested sixty-four grammes of the roe in successive portions of water as long as the liquor dissolved anything, The water being heated deposited flocks, which, being collected on a filter and dried, was gray, and dissolved completely in caustic potash. From this solution it was precipitated in white flocks by tincture of nut-galls. When distilled *per se*, it furnished an oily and very alkaline liquor, having a fetid odour. The residual charcoal being incinerated, left a small quantity of white ash, which had an alkaline reaction. It consisted of carbonate of potash, phosphate of potash, and phosphate of lime. The flocks were obviously coagulated albumen, mixed with the above-named salts.

The liquid from which the albumen had separated being evaporated to dryness, left a yellowish-brown extract, having a distinct flavour of beef-tea. When treated with strong alcohol, it only partially dissolved. The alcoholic solution, being mixed with water, was abundantly precipitated by tincture of nut-galls, acetate of lead, and nitrate of mercury. When evaporated, it left a yellowish residue soluble in water and in alcohol. From these characters, Morin considered the substance to contain osmazome. When triturated with potash, it gave out a strong smell of ammonia, which he conceived to exist in the state of sal-ammoniac. When burnt it left a white ash soluble in water, and containing carbonate of soda and chloride of potassium.

The portion of the extract left by the alcohol was totally soluble in water. The solution was precipitated in yellow flocks by tincture of nut-galls. The mineral acids occasioned no change in it. Morin considered it as gelatin. When heated it swelled up, gave out an animal odour, and left a white alkaline ash consisting of carbonate of soda and phosphate of lime.

The roe, which had been treated with water, was digested in hot alcohol. The filtered alcoholic solution was yellowish and muddy. When evaporated it left a yellow oil, having a fish smell and soluble in ether. It was identical with the oil extracted by Vauquelin from the roe of the pike. When burnt it left a minute quantity of phosphoric acid.

The residue of roe treated with water and alcohol, had the appearance of indurated albumen. It dissolved in caustic potash without giving out any ammonia. Muriatic acid dropt into the solution threw down white flocks soluble in an excess of acid. Heated in a platinum crucible, it left a charcoal difficult to inci-

nerate. It was similar in its nature to the charcoal left after heating the exhausted roe of the pike.

From his analysis Morin concludes that the roe of the common trout contains,

1. Albumen.
2. Osmazome.
3. Gelatin.
4. Oil.
5. A solid matter resembling coagulated albumen.
6. Sal-ammoniac.
7. Phosphorus.
8. Carbonate of soda.
9. Carbonate and phosphate of potash.
10. Chloride of potassium.
11. Phosphate and carbonate of lime.

3. The roe of the carp was analyzed by Morin in the same manner. He obtained,

1. Much albumen.
2. Osmazome.
3. Gelatin.
4. Oil containing phosphorus.
5. Coagulated albumen.
6. Chloride of potassium.
7. Carbonate of soda.
8. Phosphate of lime and carbonate of lime.

4. M. Dulong d'Astafort analyzed the roe of the barbel in the same way as the preceding analyses had been conducted. It has been long known that the roe of the pike has a purgative quality. And M. Dulong d'Astafort informs us that those of the barbel have the same property. This effect is ascribed to the oily matter which both contain, which, instead of being a tasteless fixed oil like that in the yolk of the common fowl, possesses very acrid properties. The roe of the barbel was found to contain the following substances:

1. Albumen.
2. An acrid oil.
3. Osmazome.
4. Gelatin.
5. Phosphorus.
6. Chlorides of potassium and sodium.
7. Sal-ammoniac.
8. Phosphates of lime and potash.
9. An organic salt, with base of potash.

These analyses show a striking analogy between the roes of fishes and the eggs of fowls.

CHAPTER XII.

OF URINE.

No animal substance has attracted more attention than *urine*, both on account of its connection with various diseases, and of the remarkable products that have been obtained from it. Mr Boyle made several attempts to determine the nature of the salts which it contained;* though, from the imperfect state of chemistry in his time, it was not possible that he could have succeeded. The discovery of phosphorus from urine by Brandt, in 1669, naturally drew the attention of chemists to that liquid. Boyle discovered the process of Brandt, and taught his operator, Godfrey Hankwitz, the method of extracting it from that liquid; and it is well known, that for many years Hankwitz was the person who supplied all the chemists in Europe with this curious substance.

The putrefaction of urine and the great quantity of ammonia which it yields when distilled, must have been observed at a very early period, and accordingly we find the facts connected with these processes described by the earliest chemists who turned their attention to urine. Lemeri, for example, whose system of chemistry was published in the latter part of the seventeenth century, has a whole chapter on the subject. Margraaf improved the process of extracting phosphorus from urine in the year 1743, and in 1746 he extracted ammonia-phosphate of soda or microcosmic salt from urine, and described its properties.†

But the first person who threw any great light upon the constituents of urine was Rouelle Junior. In his researches on urine, published in the *Journal de Medecine* for 1773 and 1777, he describes the properties of urea, which he extracted from urine by means of alcohol, and obtained in the state of crystals. To this substance he gave the name of *soapy matter*. Rouelle pointed out, likewise, some of the salts of urine, though not so successfully. In 1776, Scheele discovered uric acid in urine, and showed that it constituted one of the most common of the sub-

* Shaw's Boyle, iii. 316, 376, 377.
† Opuscules Chimiques de Margraaf, i. 30, 123.

stances by the concretion of which calculi are produced. He detected also phosphate of lime in urine.*

In 1808, Berzelius published the second volume of his *Animal Chemistry,* in which he gives a long account of the properties of urine, and mentions the action of reagents on it, but gives no quantitive analysis. His well-known analysis of urine appeared first in his paper entitled *General Views of the Composition of Animal Fluids,* published in 1813 in the third volume of the Medico-Chirurgical Transactions.†

About ten years after this, I made many experiments on urine, and likewise analyzed this liquid from a healthy individual; but the paper lay by me unpublished till it was inserted in the second volume of the *Records of General Science* in 1835. In 1839, an elaborate paper on the variation of the constituents of urine in the same and in different individuals was given to the public by M. Lecanu.‡ Of this important paper an abstract will be given in this chapter.

Urine is secreted by the kidneys and conveyed by the ureters to the bladder, from which it is voided occasionally when its presence gives rise to a feeling of uneasiness. It was generally supposed by physiologists that the solid substances which it holds in solution were formed by the action of the kidneys; but the experiments of Prevost and Dumas have made it almost certain that they all exist in the blood, and that the office which the kidney performs is only to separate them from the other constituents with which they are mixed in the blood-vessels. For when they extirpated the kidneys from animals and examined their blood two or three days afterwards, they were able to detect in it a sensible quantity of urea.

Human urine when newly emitted has a yellow colour, more or less deep, according to circumstances. It is transparent, though sometimes when left at rest in a glass it deposits a few flocks of mucus. It has a distinct aromatic smell, which has been compared to that of violets. When it cools, the aromatic smell leaves it, and is succeeded by another well-known by the name of *urinous.* This odour is in two or three days (when the urine is from young or middle-aged persons) succeeded by another which has

* Scheele's Essays, p. 199. † Annals of Philosophy, ii. 422.
‡ Jour. de Pharmacie, xxv. 681, 746.

considerable resemblance to that of sour milk. This smell gradually passes off in its turn, and is succeeded by a fetid ammoniacal odour. This odour appears much sooner in the urine of old individuals than in that of young persons. It has a disagreeable, bitter, saline taste, of very various degrees of intensity, sometimes so slight that it can barely be perceived. In such cases, the urine is nearly colourless ; when high-coloured, the taste is always strong.

Nothing is more various than the colour of urine. Most commonly it is yellow, of various shades. Sometimes it passes into orange, or even into red. It is said to be deeper in men than in women, but I have not been able to satisfy myself that such a difference exists. There is an intimate connection between the depth of the shade and the quantity emitted. When the urine is scanty it is always high-coloured ; hence one reason of the red colour of urine in fevers. When the quantity emitted is great the colour is pale. I have seen it in cases of hysteria so nearly colourless that the presence of the usual constituents of urine could only be discovered by concentrating it. By this treatment it gradually acquires the yellow colour of common urine, and may be even made red by carrying the concentration farther. Sometimes urine contains bile, which gives it an orange tint. Muriatic acid changes the colour of urine containing bile to green. Occasionally the colour of urine is so deep that it appears *black*. This change is sometimes owing to a mixture of blood ; but sometimes to substances taken into the stomach. Thus, when preparations of iron are given at the same time with rhubarb the urine is said to assume a blackish colour. Urine has frequently a *red* colour, and the shade varies from rose-red to scarlet. Red urine usually characterizes an inflammatory state of the system. Such urine is always scanty. Other colours are mentioned by medical men. Thus urine has been described as *grayish, greenish*, and *buff*-coloured. Dr Prout mentions a case in which it threw up a cream-like milk. Such urine might be called *white*, and probably owed its peculiar qualities to the presence of chyle.

Lecanu* examined 93 different specimens of urine, and has given us the following table of their colours :

28 had a light-yellow colour.

* Jour. de Pharmacie, xxv. 694.

24 had a deep-yellow colour.
27 had a red colour.
7 had a greenish colour.
7 had a brown colour.*

The smell of urine is varied by causes apparently trifling. Asparagus gives it a peculiar fetid odour, while oil of turpentine taken into the stomach soon communicates to urine the smell of violets. In many individuals almost every article of food produces a corresponding change on the odour of urine. In the disease called *diabetes* the urine has a peculiar odour, not easily described. Perhaps the term sweetish might be applied to it.

The specific gravity of urine varies very much according to circumstances. The following table exhibits the extremes as stated by various chemists and physiologists:

	Cruikshanks.	Chossat.	Lecanu.	Thomson.
Maximum,	1·033	1·0388	1·038	1·048
Minimum,	1·005	1·0016	1·010	1·000148

Both of the urines whose specific gravity were determined by me, were the urines of disease. The first in a case of diabetes, and the second in a case of hysteria.

The following table exhibits the mean specific gravity of the urine of eight individuals experimented on by Chossat.† The second column gives the mean quantity of solid matter in the urine of each individual passed in twenty-four hours:

	Sp. gravity.	Solid contents in Grains.
	1·0127	307·5
	1·0156	389.
	1·0178	390·6
	1·0213	500·4
	1·0222	513·1
	1·0232	534·3
	1·0240	510·9
	1·0264	568·2
Mean,	1·0204	464·25

According to this table of Chossat the mean specific gravity of urine in a state of health is 1·0204. I have found the mean spe-

* Jour. de Pharm. xxvi. 202.

† Jour. de Physiol. v. 197.

cific gravity of the urine of a middle aged man in perfect health to be 1·01385. It varied in the course of a fortnight from 1·0093 to 1·0192. But it was observed occasionally as high as 1·0266. Lecanu found the mean specific gravity of the urine of young men greater than that of old persons.* According to Becquerel the mean specific gravity of urine is as follows:

In males,	. .	1·0180
In females,	. .	1·01512
Mean,	.	1·01656

I found in a healthy middle aged individual the mean quantity of urine voided in twenty-four hours, amount to 3⅓ lbs. avoirdupois. But it varied a great deal, being sometimes as low as 2·133 lbs., and sometimes as high as 4·857 lbs.

Lecanu has given us a considerable series of facts on the quantity of urine voided by different individuals in twenty-four hours:

In thirteen individuals it varied from 1·16 lbs. to 5·007 lbs.

In five young men from the age of 20 to that of 40 years, the quantity of urine voided in 24 hours, varied from 1·64 lbs. to 5·007 lbs.

In young men the quantity of urine voided is greater than in old men or in infants.

When we take the mean of a number of days, the quantity of urine voided in 24 hours by different individuals approaches much nearer to equality.

The mean of 48 experiments gives 2·795 lbs. avoirdupois for the quantity of urine voided in 24 hours.

Haller states it at		3·457 lbs.
Prout at,	.	2·300
Bostock,	.	2·822
Rayer,	.	2·771
Lecanu,	.	2·795
Thomson,	.	3·333
Mean,	.	2·913, or very nearly 3 lbs. avoirdupois.

According to Becquerel,† the mean quantity of urine in 24 hours, is,

* Jour. de Pharmacie, xxv. 695.

† Semeiotique des Urine, p. 6.

In males, 2·794 lbs. avoirdupois.
In females 3·024 lbs.
Mean, . 2·909 lbs.

This agrees nearly with the result of Lecanu.

The quantity of urine depends partly upon the quantity and nature of the food. The average quantity is greater when the food is generous and abundant than when it is meagre and scanty. Chossat found, however, that the quantity of urine voided was greater when the food was bread than when it was restricted to flesh meat. He found also that the secretion of urine is dimished in the evening. But to this there must be many exceptions; for I did not find it so in the cases that came under my observation.

A good deal of loose statements have been made respecting the quantity of urine voided at different times of the day, and respecting the specific gravity of the urine when so voided; perhaps the following table may not be altogether useless. The experiments were made on the urine of a healthy individual between 50 and 60 years of age, and complete reliance may be placed upon the results, as every precaution was taken to insure accuracy:

September 23d.			September 24th.		
When voided.	Cub. in. at 95°.	Sp. gravity at 60°.	When voided.	Cub. in. at 95°.	Sp. gravity. at 60°.
11 A. M.	4·	1·0192	11 A. M.	5·75	1·0173
1 P. M.	7·75	1·0165	12¾ P. M.	6·75	1·01605
2½	4·8	1·0126	1¼	9·75	1·0069
3¾	3·5	1·0176	2¼	8·	1·00808
4½	4·8	1·0186	4¼	5·75	1·0136
9¾	7·5	1·0206	5¾	5·5	1·0146
11¼	4·0	1·0226	9½	8·2	1·0186
1 A. M.	14·0	—	12	10·	1·0146
4	24·0	1·0126	4 A. M.	23·	1·0115
7½	9·75	1·0106	8	10·25	1·0136
8¼	6·25	1·0126	8⅝	3·75	1·0156
9	4·50	1·0156	—	—	—
Total, .	94·85 or 3·403 lbs.		Total, .	96·7 or 3·47 lbs.	
	Mean, .	1·01249		Mean, .	1·01301

September 25th.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
$11\frac{3}{4}$ A. M.	6·	1·0187
1 P. M.	7·5	1·0113
$2\frac{1}{4}$	4·8	1·0101
$3\frac{1}{3}$	5·5	1·00958
$5\frac{3}{4}$	6·5	1·0126
10	8·8	1·0166
$11\frac{1}{4}$	8·5	1·01059
5 A. M.	25·5	1·01059
8	8·	1·01059
$8\frac{3}{4}$	5·5	1·0115
...	..	...
...	...	...
...	...	...
...	...	...
Total,	86·6 or 3·1 lbs.	
	Mean,	1·01156

September 26th.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
11 A. M.	8·8	1·0126
Noon,	7·5	1·0086
$1\frac{1}{2}$ P. M.	8·	1·0114
$2\frac{2}{3}$	7·	1·0101
5	5·	1·0156
$6\frac{1}{4}$	8·5	1·0055
$9\frac{1}{3}$	7·8	1·0126
$10\frac{1}{3}$	8·25	1·0065
11	6·25	1·0065
$11\frac{1}{2}$	3·66	1·0065
3 A. M.	23	1·0065
6	18·8	1·0086
$8\frac{1}{4}$	13·5	1·0065
$8\frac{3}{4}$	8·	1·0086
Total,	134·06 or 4·875 lbs.	
	Mean,	1·0093

September 27th.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
$10\frac{1}{3}$ A. M.	4·	1·0246
Noon,	8·8	1·0117
$12\frac{1}{2}$ P. M.	8·2	1·0047
$1\frac{1}{3}$	7·8	1·0082
$2\frac{1}{4}$	6·	1·0082
4	5·8	1·0106
6	6·25	1·0115
$7\frac{2}{3}$	2·25	1·0166
$11\frac{1}{2}$	7·8	1·0216
$5\frac{1}{2}$ A. M.	20·	1·0106
8	11·	1·0106
9	6·5	1·0106
Total,	94·4 or 3·424 lbs.	
	Mean,	1·01199

October 1st.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
11 A. M.	4·5	1·0204
$1\frac{1}{2}$ P. M.	6·5	1·0175
$3\frac{1}{2}$	6·75	1·0111
$5\frac{1}{2}$	4·8	1·0156
10	9·	1·0146
$11\frac{1}{3}$	16·	1·0096
$5\frac{3}{4}$ A. M.	25·	1·0075
8	9·	1·0101
$8\frac{1}{2}$	5·75	1·0101
...	...	...
...	...	...
...	...	...
Total,	87·3 or 3·17 lbs.	
	Mean,	1·0111

October 2d.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
$11\frac{2}{3}$ A. M.	6·25	1·0197
$1\frac{1}{2}$ P. M.	4·	1·0197
$4\frac{1}{4}$	4·	1·0188
6	4·	1·0201
$10\frac{1}{2}$	5·25	1·0226
11	5·25	1·0216
$5\frac{2}{3}$ A. M.	25·	1·0086
8	11·5	1·0086
$8\frac{1}{2}$	7·	1·0106
Total, .	72·75 or 2·626 lbs.	
	Mean, .	1·0134

October 3d.

When voided.	Cub. in. at 95°.	Spr. gr. at 60°.
$11\frac{1}{3}$ A. M.	6·	1·0192
$1\frac{1}{2}$ P. M.	8·75	1·0152
$3\frac{3}{4}$	6·5	1·0136
$4\frac{1}{4}$	3·25	1·0206
6	1·8	1·0206
10	6·	1·0246
$11\frac{1}{3}$	4·	1·0266
$6\frac{1}{3}$ A. M.	12·5	1·0246
8	9·25	1·0176
$8\frac{3}{4}$	10·5	1·0146
Total, .	68·55 or $2\frac{1}{2}$ lbs.	
	Mean, .	1·0192

October 4th.			October 5th.		
When voided.	Cub. in. at 95°.	Sp. gr. at 60°.	When voided.	Cub. in. at 95°.	Sp. gr. at 60°.
11¼ A. M.	8·5	1·01809	Noon	7.75	1·0186
12¼ P. M.	8·	1·0134	1 P. M.	8.5	1·0098
1	14·75	1·0077	1¾	7·	1·0098
3⅙	9·5	1·00958	4	7·2	1·0115
5	4·8	1.0131	5⅓	5·	1·0146
9½	8·5	1·0176	10	5·	1·0216
12	8·5	1·0166	11¾	2·	1·0256
6 A. M.	24·	1·00958	7¾ A. M.	12·	1·0256
8	13·	1·00958	8⅓	4·	1·0236
8½	3·	1·0106			
Total,	102·55 or 4·386 lbs.		Total,	58·48 or 2·133 lbs.	
	Mean,	1·0192		Mean,	1·0173

From the inspection of the preceding tables it will be at once apparent how very various the urine is both in its quantity and specific gravity, even when the individual voiding it enjoys perfect health.

The mean specific gravity of the urine passed during these ten days is 1·013859. The lowest specific gravity is 1·0047, and the highest, 1·0266.

The mean quantity passed per day was 90·91 cubic inches, or 3·307 lbs. avoirdupois. The least passed on any day was 58·15 cubic inches, or 2·133 lbs.; the greatest quantity was 133·37 cubic inches, or 4·857 lbs.

The preceding tables do not tally well with the universally received opinion that the heaviest urine is that which is passed on getting up in the morning. This was not the case in any one of the ten days contained in the tables. On the contrary, the lightest urine passed on the 23d of September, the 1st October, and the 2d of October was that of the morning, and on all the other days, save one, the lightest urine was that passed between twelve and four P. M. from four to eight hours after breakfast, but before dinner.* On the contrary, the heaviest urine was in one case passed one hour after dinner, and generally from three and a-half to five and a-half hours after a meal.

I made a comparison between the liquid taken into the sto-

* Breakfast was between eight and nine A. M. dinner at four P. M., and tea at six P. M. There was no supper.

mach and the urine passed for five consecutive days. Some days the urine exceeded the drink; but upon the whole, the drink was to the urine nearly as eleven to ten. On one day the drink was to the urine as 100 : 68·2, on another as 73¼ : 102·02. If the induction were sufficient, it would follow that the drink exceeds the urine by one-tenth part. Hence if the mean quantity of urine voided by 2·913 lbs., that of the drink will be 3·204 lbs. Chossat states that in his very numerous trials, the average quantity of drink was to that of the urine as ten to nine nearly. Varying somewhat according to the temperature, the quantity of urine being greatest in the coldest weather.

The number of times that urine is voided in twenty-four hours varies greatly in different individuals. I know an individual who enjoys good health, and who passes urine at an average only three or four times a-day. The greatest number of times in the preceding tables is fourteen times and the smallest nine times.

When urine is voided from a person in perfect health, it always contains an uncombined acid; for it reddens litmus-paper, and the change is permanent, and therefore not owing to carbonic acid. Various opinions have been stated respecting the nature of this acid. Proust and Fourcroy and Vauquelin supposed it to be the *phosphoric*. Urine contains a small quantity of phosphate of lime, which may be precipitated from it by by caustic ammonia. Now, as phosphate of lime is insoluble in water, while a little of it is actually held in solution in urine, it was not unreasonable to conjecture that it was in the state of biphosphate of lime, which is slightly soluble in water, and capable of reddening litmus-paper. But a very simple experiment is sufficient to show that urine contains no biphosphate of lime. Evaporate urine to dryness, and ignite the residue. The residual salts do not act on litmus-paper. Hence the free acid must be volatile, since it is dissipated by a red heat.

Berzelius affirms that urine contains lactate of ammonia and free lactic acid. I have not been able to verify this statement by experiment; the quantity obtained being always too small to enable me to investigate its nature. I mixed sulphuric acid with fresh urine till it tasted distinctly acid, and distilled over a third of the mixture from a glass retort, by means of a gentle heat. The liquid thus obtained was tasteless, and had no per-

ceptible smell. It slightly reddened litmus-paper. It was mixed with carbonate of soda, till it became slightly alkaline. Being now evaporated to dryness, and a drop of sulphuric acid let fall upon the small saline residue, a smell was emitted strongly urinous, but mixed with a sensible odour of vinegar. Hence it was obvious that acetic acid existed in the residue. But it might have been formed from lactic acid during the process. For Scheele showed long ago that lactic acid is very easily converted into acetic acid.

Urine contains always some *uric acid*, as was first observed by Scheele. It separates in minute crystals when the urine is mixed with nitric acid, and set aside for some time in an open glass vessel. Berzelius states the average quantity of uric acid in urine at $\frac{1}{1000}$th of its weight. Lecanu states the uric acid in 100 urine to be 0·75. A copious table of the quantity of uric acid in many different specimens of urine, as determined by Lecanu, will be given in a subsequent part of the present chapter. I found that 1000 parts of urine of the specific gravity 10·185 let fall 0·242 of uric acid when mixed with nitric acid. Now, according to the experiments of Prout, uric acid does not dissolve in 10,000 times its weight of water, while urate of ammonia is soluble in about 500 times its weight of that fluid. Hence it is natural to infer that uric acid in urine is in the state of urate of ammonia. And, as urate of ammonia reddens vegetable blues, the acidity of the urine may be partly owing to the presence of urate of ammonia.

The most remarkable substance in urine is *urea*. According to Berzelius, it exists in urine to the amount of 3 per cent. But he does not give us the specific gravity of the urine tried. Lecanu found that urine of sp. gr. 1·030 contained 2·94 per cent. I obtained from urine of specific gravity 1·0185 2·364 per cent. of urea. A copious table of the quantity contained in different urines will be given at the end of this chapter.

Besides these substances, and the colouring matter, which has not hitherto been obtained in a separate state, urine contains always phosphoric and sulphuric acids, together with lime, magnesia, potash, and ammonia, and a notable quantity of common salt.

The first analysis of urine was published by Berzelius in 1813. He does not give the specific gravity of the urine examined by him. But he states that it became turbid on standing. Hence

it could not have been the urine of a healthy individual. The result of his analysis was as follows:

Water,	933·00
Urea,*	30·10
Sulphate of potash,	3·71
Sulphate of soda,	3·16
Phosphate of soda,	2·94
Common salt,	4·45
Phosphate of ammonia,	1·65
Sal-ammoniac,	1·50
Free lactic acid, Lactate of ammonia, Animal matter soluble in alcohol, and accompanying the lactates, Animal matter insoluble in alcohol, Urea not separated,	17 14
Earthy phosphates, with trace of fluate of lime,	1·00
Uric acid,	1·00
Mucus of the bladder,	0·32
Silica,	0·03
	1000·†

I made an analysis of healthy urine of specific gravity 1·0185 about the year 1824, and obtained from 1000 grains of it the following substances:

Phosphate of lime,	0·209
Phosphoric acid,	1·131
Sulphuric acid,	0·481
Chlorine,	5·782
Uric acid,	0·242
Soda,	4·610

* MM. Cap and Henry have shown by experiments which appear conclusive, that the urea in urine is in the state of lactate, being combined with lactic acid. See Jour. de Pharm. xxv. 133.

Lactate of urea is composed of,

1 atom lactic acid,	8·875
1 atom urea,	7·5
	16·375

† Annals of Philosophy, ii. 423.

Potash, . .	2·051
Ammonia, . .	0·130
Urea, . .	23·640
	38·276

and I considered that these substances were combined so as to form the following bodies:

Urate of ammonia, .	0·298
Sal-ammonia, .	0·459
Sulphate of potash, .	2·112
Chloride of potassium, .	3·674
Chloride of sodium,	15·060
Phosphate of soda, .	4·267
Phosphate of lime, .	0·209
Acetate of soda, .	2·770
Urea with colouring matter,	23·640
	52·489

The rest of the weight consisted of water together with a free acid, which may be the lactic.*

But by far the most numerous set of experiments on the constitution of urine has been made by M. Lecanu. His object was to determine the quantity of urine voided in twenty-four hours, its specific gravity, and the weight of the urea, uric acid, and salts which each urine contained. Before giving the table of his results, it will be worth while to state the general facts brought to light by his numerous experiments. They may be stated very shortly.

1. The urine of young men has usually a higher specific gravity than that of old men or infants.

2. The quantity of urea voided in twenty-four hours is very different in different individuals. One man, for instance, voided 509·3 grains, and another only 185·3 grains.

3. But in the same individual the quantity of urea voided in twenty-four hours does not vary much, as will appear from the following table of Lecanu:†

In A,‡ it varied from 334·9 grains to 478·4 grains.

B, . 360·4 . 478·4

* Records of General Science, ii. 13. † Jour. de Pharmacie, xxv. 746.

‡ These letters refer to the individuals whose urine is given in a subsequent table.

C,	334·9	457·5
D,	416·7	463·0
E,	416·7	509·3
H,	154·3	185·2

4. When the aqueous portion of the urine is increased, the quantity of urea voided does not undergo a corresponding increase.

5. The quantity of urea does not bear a constant ratio to the specific gravity of the urine.

6. The quantity of uric acid voided in twenty-four hours was found to vary from 1·373 grains to 14·307 grains.

7. Healthy urine contains from $\frac{1}{392}$ to $\frac{1}{10000}$th of its weight of uric acid.

8. The uric acid voided does not bear a constant ratio to the quantity of urine.

9. The quantity of fixed salts in urine varies in twenty-four hours from 378 grains to 74·8 grains.

10. The earthy phosphates voided in twenty-four hours were found to vary from 30·25 to 0·447 grains. There is no difference between the quantity of these salts in the urine of infants and of young men; but the quantity in the urine of old persons is sensibly less.

11. The quantity of common salt in urine voided in twenty-four hours varies from 116·5 to 0·247 grain.

12. The quantity of sulphuric acid in urine voided in twenty-four hours varies from 57·5 to 15·25 grains.

13. The quantity of phosphoric acid in the phosphate of soda and ammonia contained in urine voided in twenty-four hours, varies from 25·37 to 0·17 grain.

From these facts Lecanu has drawn the following conclusions:—

1. In the same individual the urea is secreted in equal quantities in equal times.

2. Uric acid, also, in the same individual, is secreted in equal quantities in equal times.

3. The secretion of urea and uric acid varies very much in different individuals during equal times.

4. The variable quantities of urea which different individuals secrete during equal times, bear a constant ratio to the sex and

age of the individuals. They are greater in men in the vigour of life than in women in the same vigour of life. They are greater in middle-aged women than in old persons or infants.

5. The fixed constituents of urine not driven off by heat, namely,

The earthy phosphates,
Common salt,
The alkaline sulphates and phosphates,

are secreted in variable quantities, having no relation to the sex or age, by different individuals, and also by the same individuals at different times.

The following table, exhibiting the result of M. Lecanu's experiments, conveys a great deal of important information in a small compass:

No. of experiments.	Urine voided in 24 hours in gr.	Sp. gravity of urine.	Uric acid in 24 hours in grains.	Urea in 24 hours in grains.	Mucus voided in 24 hours in grains.	
1	14168	1·0301	10·63	420 44		
2	14284	1·0309	24·31	365·85		
3	14908	1·0316	19·83	403·02		
4	17362	1·0163	12·16	427·68		
5	11456	1·0186	14·21	437·50		
6	12084	1·0309	17·68	423·77		
7	18828	1·0265	16·95	478·98	17.44	A
8	13828	1·0265	11·38	410·41		
9	13705	1·0272	14·23	413·85		
10	13226	1 0301	13·75	462·62		
11	15201	1·0272	19.44	483·41		
12	25680	1·0238	9·75	436·37		
13	15804	1·0301	14·38	452·23		
14	14615	1·0301	9·94	402 83		
15	14090	1·0238	7·90	373·39		
16	14001	1·0301	11·77	422·79		
17	17486	1·0163	20·63	481·93		
18	13967	1·0301	12.02	473·75	26·54	B
19	14507	1 0316	12·47	422·88		
20	14695	1·0309	13·78	466·23		
21	14229	1 0265	23 61	422·38		
22	13797	1·0301	18·21	394·87		
23	16791	1·0275	20·48	462·76		
24	14646	1·0301	19·48	395·80		

* Jour. de Pharmacie, xxv. 758.

No. of experiments.	Urine voided in 24 hours in gr.	Sp. gravity of urine.	Uric acid voided in 24 hours in grains.	Urea in 24 hours in grains.	Mucus voided in 24 hours in grains.	
25	17578	1·0386	17·58	462·60		
26	13920	...	19·00	360·56		
27	15279	1·0275	8·91	372·57		
28	15495	1·0275	20·16	459·92		
29	13411	1·0386	17·98	437·67	19·60	C.
30	12686	1·0316	21·82	376·26		
31	12485	1·0386	18·74	357·35		
32	16791	1·0267	14·04			
33	60575	1·0107	...	419·20		
34	48845	1·0137	...	465·89		
35	33150	1·0117	23·35	456.82	25.16	D.
36	31452	1·0195		466·80		
37	26437	1·0232	5·82	501·06		
38	25897	1·0225	6·99	480·28		
39	22162	1·0210	3·78	446·35	4·81	E.
40	26885	1·0172	4·85	484·63		
41	29415	1·0180	2·36	467·70		
42	29817	1·0180	4·17	426·63		
43	31422	1·0210	4·40	283·09		
44	35048	1·0217	3·50	371·47		
45	24801	1·0230	8·92	379·90		
46	30125	1·0208	4·22	383·03		
47	33798	1·0225	5·54	447·82		
48	34778	1·0180	3·47	331·84	5·86	F.
49	29554	1·0202	7·08	235·00		
50	28396	1·0195	2·84	179·95		
51	30712	1·0195	8·21	248·66		
52	30249	1·0217	13·89	272·70		
53	8812	1·0217	4·64	92·01		
54	10957	1·0207	5·48	92·91		
55	10741	1·0202	6·23	96·02		
56	8519	1·0202	3·92	72·23	1·00	G.
57	9291	1·0172	3·54	60·35		
58	11760	1·0180	3·06	87·27		
59	10155	1·0202	3·86	161·46		
60	16050	1·0149	2·25	187·13		
61	12346	1·0189	3·70	183·22		H
62	...	1·0100	1·94	189·26		

No. of experiments.	Urine voided in 24 hours in gr.	Sp. gravity of urine.	Uric acid voided in 24 hours in grains.	Urea in 24 hours in grains.	Mucus voided in 24 hours in grains.	
63	28057	1·0187	6·71	297·51		
64	18612	1·0208	10·79	276·22		
65	23782	1·0195	5·89	252·08		
66	17748	1·0232	7·45	262·57		
67	17205	1·0217	6·22	238·18	5·79	I.
68	15927	1·0202	6·05	208·14		
69	23665	1·0224	7·92	343·54		
70	31560	1·0144	7·25	250·90		
71	11667	1·0223	6·76	173·16		
72	8411	1·0253	7·08	187·22	2·08	J.
73	8257	1·0238	7·10	153·19		
74	14430	1·0238	11·25	309·61		
75	11651		7·90	370·53		
76	16822	1·0268	10·76	436·86	4·81	K.
77	14815	1·0208	6·53	290·54		
78	9661	1·0227	4·24	245·56		
79	14584	1·0241	10·50	340·10	0·45	L.
80	12578	1·0208	6·28	235·97		
81	8102	1·0324	5·66	266·24		
82	15232	1·0202	2·75	193·70		
83	15680	1·0187	1·88	216·10		M.
84	8441	1·0215	3·87	219·20		
85	10417	1·0230	1·66	253·73		
86	10787	1·0230	5·60	161·26		
87	10390	1·0238	5·17	246·53	Quantity imponderable.	N.
88	9630	1·0238	4·31	254·09		
89	8581	1·0268	1·37	209·15		
90	3503	1·0245	0·96	65·44		
91	3472	1·0215	0·89	57·26		O.
92	5016	1·0238	1·08	81·80		
93	4275	1·0227	2·47	81·80		P.

To understand this table fully, the following observations will be necessary:—

1. The urine A, from 1 to 12 inclusive, was voided by a young man of twenty years of age, of a lymphatic temperament, leading an active life, and using an abundant and varied diet.

2. The urine B, from 13 to 24 inclusive, was voided by a young

man of 22, of a good constitution, of a sanguine temperament, leading the same life, and living in the same way as A.

3. Urine C, from 25 to 32 inclusive, was from a man aged 38 years, of a good constitution, of a lymphatico-sanguine temperament, leading an active life, and using an abundant and varied diet.

4. Urine D, from 33 to 36 inclusive, was from a man of 43 years of age, of a good constitution, of a lymphatico-sanguine temperament, confined to bed from a rupture of the perineum. His food was soup in the morning, meat and soup at noon, soup, meat, and vegetables at five P. M., and from twelve to eighteen ounces of wine daily. When thirsty, he drank barley-water sweetened with honey.

5. Urine E, from 37 to 42 inclusive, from a man of 35 years of age, of an athletic constitution, a bilious temperament, confined to his chamber in consequence of a fracture of one of the clavicles. His food was similar to that of D.

6. Urine F, from 43 to 52 inclusive, from a man aged 38 years, of a good constitution, a lymphatic temperament, taking abundant and varied nourishment, and a good deal of exercise.

7. Urine G, from 53 to 58 inclusive, voided by an old man of 86 years of age, of a sanguine temperament, free from infirmity, and living well.

8. Urine H, from 59 to 62 inclusive, voided by an old man of 85, of a good constitution, a sanguine temperament, his urinary organs sound, and living well.

9. Urine I, from 63 to 70 inclusive, voided by a woman of 28 years of age, of a sanguine temperament, of a good constitution, using an abundant and varied diet and moderate exercise.

10. Urine J, from 71 to 73 inclusive, from a woman of 43, of a good constitution, a bilious temperament, subjected to a good alimentary regimen.

11. Urine K, from 74 to 77 inclusive, from a girl aged 19, of a good constitution, a lymphatico-sanguine temperament, subjected to a good alimentary regimen.

12. Urine L, from 78 to 81 inclusive, from a girl of 19, of a good constitution, a lymphatic temperament, and well fed.

13. Urine M, from 82 to 85 inclusive, from a boy aged 8 years, in robust health, of a sanguine temperament, and confined to bed from a wound in the leg.

14. Urine N, from 86 to to 89 inclusive, from a boy of 8 years, of a good constitution, and a sanguine temperament, confined to bed for a phymosis.

15. Urine O, from 90 to 92 inclusive, from an infant of 3 years, a robust constitution, and a sanguine temperament.

16. Urine P, No. 93, from a child of 4 years, of a good size, and a lymphatic temperament.

17. The whole of the urine voided by the children O and P could not be collected. M. Lecanu conceives that the half of it was lost.

18. The temperature at which the specific gravity of the urine was taken varied from 68° to 46°, but most commonly it was between 50° and 60°.

19. The greatest quantity of urine voided in twenty-four hours was No. 33. It amounted to 30575 grains, or 8·65 pounds avoirdupois, but in four days the quantity was reduced to 31452 grains, or 4·49 pounds avoirdupois. The smallest quantity (except that of infants) was No. 73, 8257 grains, or 1·18 pounds, voided by a woman of 43 years of age.

20. The highest specific gravity was 1·0386, and the lowest, 1·0100.

MM. Cap and Henri are of opinion that urea exists in urine in the state of lactate of urea, and they have shown by experiments, which appear conclusive, that healthy urine actually contains lactate of urea.* But it would be difficult to prove that all the urea in healthy urine is in the state of lactate.

Dr Alfred Becquerel † has lately analyzed a great number of urines, both from individuals in health and disease. The following table exhibits the mean quantity, the specific gravity, and the relative constituents of healthy urine deduced from the analysis of the urine of eight healthy individuals, four males, and four females:

	In males.	In females.
Mean quantity in twenty-four hours, .	2·794 lbs.	3·024 lbs.
Mean specific gravity, . .	1·0180	1·01512
Mean quantity of water, . .	2·7070	2·948
Do. of solid constituents, .	0·0870	0·0754
Do. of urea, . . .	0·0386	0·03433
Do. of uric acid, . .	0·0010	0·00122

* Jour. de Pharm. xxvii. 355. † Semeiotique des Urine, p. 7.

	In males.	In females.
Mean of fixed salts capable of ignition,	0·0214	0·01855
Do. of organic salts,	0·0260	0·02130
Means, supposing the urine to weigh 1000.		
Mean water,	968·815	971·935
solid constituents,	31·185	28·066
urea,	13·838	12·102
uric acid,	0·557	0·398
fixed salts,	8·426	6·919
organic salts,	9·655	8·647

The fixed salts were chlorides, phosphates, and sulphates of lime, soda, potash, and magnesia. The organic salts were lactate of ammonia, lactic acid, colouring matter, extractive matters, sal-ammoniac, and perhaps lactate of urea.

Such are the properties, and such the constituents of human urine in a state of health. But this excretion is singularly modified by disease, and the changes to which it is liable have attracted the attention of physicians in all ages, as serving to point out the state of the patient, and the progress of the disease under which he labours. It is greatly to be regretted that but few accurate chemical examinations of the urine of individuals labouring under particular diseases have yet been made. The few general observations that have been made by medical men are the following :—

M. Alfred Becquerel has made many analyses of diseased urine to determine the alterations which take place in its constituents. The following abstract exhibits the most important facts which he determined :

1. The quantity of uric acid is augmented by fever and by functional disorders, such as diseases of the heart, lungs, liver, &c. When it is superabundant, the urine deposits a sediment of uric acid. It is diminished in chlorosis, anemia, great prostration of strength:

Mean normal quantity in 24 hours, sp. gr.	1·016437
water in 24 hours,	1·302 lbs.
uric acid in do.	0·00123 lbs.
Mean excess,	1·021654
water in 24 hours,	1·441 lbs.
uric acid in do.	0·0023 lbs.
Mean deficiency,	1·011855
water in 24 hours,	2·3832 lbs.
uric acid in do.	0·00048 lbs.

2. The urea seldom exceeds the normal quantity. It is often deficient.

Normal quantity.

Sp. gr. 1·01656.

Water in 24 hours,	.	2·8275 lbs.
Urea in 24 hours,	.	0·03646

(1.) In erysipelas, fever, bronchitis, &c.

Sp. gr. 1·021014.

Water in 24 hours,	.	1·5394 lbs.
Urea in do.	. .	0·0198

(2.) Pale urine in chlorosis, anemia, prostration of strength from loss of blood, tedious diseases, &c.

Sp. gr. 1·011837.

Water in 24 hours,	.	2·56 lbs.
Urea in do.	.	0·01543

(3.) Urine from persons exhausted by disease, excessive bleeding by leeches, &c.

Sp. gr. 1·01488.

Water in 24 hours,	.	1·3116 lbs.
Urea in do.	.	0·01084

3. *Fixed salts.*—The variation in the quantity of fixed salts resembles that of urea, as will appear by the following statement:

(1.) Normal urine.

Sp. gr. 1·01656.

Water in 24 hours,	.	2·8275 lbs.
Fixed salts in do.	.	0·01997

(2.) In fevers with great prostration of strength, diminished urea and water.

Sp. gr. 1·022218.

Water in 24 hours,	.	1·3696
Fixed salts in do.	.	0·01157

(3.) In chlorosis, anemia, debility from evacuation.

Sp. gr. 1·011063.

Water in 24 hours,	.	2·153 lbs.
Fixed salts in do.	.	0·0094

(4.) In fever with functionary disorders. Water diminished,

Sp. gr. 1·024952.

Water in 24 hours,	.	1·5346 lbs.
Fixed salts in do.	.	0·00968

(5.) In the same diseases. Quantity of water not diminished,

Sp. gr. 10·11550.
Water in 24 hours, . . 2·6704 lbs.
Fixed salts in do. . 0·007485

(6.) In anemia, chlorosis, jaundice.
Sp. gr. 1·016100
Water in 24 hours, . 2·6418
Fixed salts in do. . 0·02314

When much water is thrown into the system, all the constituents of urine are increased.

4. Organic salts, &c.

(1.) Normal quantity.
Sp. gr. 1·01656.
Water in 24 hours, . 2·8275 lbs.
Organic salts in do. 0·0236

(2.) In fever with functional disorders,
Sp. gr. 1·020740.
Water in 24 hours, . 1·5943 lbs.
Organic salts in do. . 0·021656

(3.) In similar diseases with great debility which diminishes all the constituents of urine.
Sp. gr. 1·014952.
Water in 24 hours, . 1·5346
Organic salts in do. . 0·0156

(4.) In similar disorders with diseases of the heart or liver,
Sp. gr. 1·010500.
Water in 24 hours, . 2·8336
Organic salts in do. . 0·02088

(5.) In extreme weakness, anemia, chlorosis, long diseases.
Sp. gr. 1·012390
Water in 24 hours, . 2·3691 lbs.
Organic salts in do. . 0·0178

The urea in urine is often changed into carbonate of ammonia.

1. In *dyspepsia,* according to Thenard, the urine putrefies very rapidly, and is copiously precipitated by the infusion of nutgalls.

2. In *inflammatory* diseases the urine is of a red colour, scanty, and peculiarly acrid. It deposits no sediment on standing, but with corrosive sublimate it yields a copious precipitate.

3. In slow *nervous fevers* the urine, according to Fromherz and Gugert,* is dark-coloured, and deposits a yellowish-red sediment, consisting of *uric* acid with a little colouring matter and mucus. The urine contains very little urea, less phosphate of lime than usual, but a great deal of phosphate of magnesia.

Mr Macgregor found the quantity of urea passed in fever and small-pox nearly the same as in health.

4. In *gout*, according to Fromherz and Gugert,† the urine, some time before the paroxysm, was found to contain no uric acid and very little phosphates. The urine of another patient voided, just before the paroxysm, was also destitute of uric acid, but contained more than usual of the phosphates. During the fit, (as in other fevers,) the free acid in urine diminishes and disappears. The uric acid augments much during the fit. This is evident from the deposition of *chalk* stones in the joints of gouty patients, which Dr Wollaston showed to consist of *urate of soda*.‡

5. During *jaundice*, the urine has an orange-yellow colour, and communicates the same tint to linen. Muriatic acid sometimes renders this urine green, and thus detects in it the matter of bile. In gout the urine sometimes contains a yellow matter, similar to what Thenard called the *yellow matter* of bile. This substance is only suspended, and may be separated by the filter. Tiedemann and Gmelin found that the urine of patients labouring under jaundice is precipitated yellow by the sulphate of iron, the perchloride of iron, the protochloride of tin, the acetate of lead, the protonitrate of mercury, and corrosive sublimate. Sulphate of copper throws down a dirty green precipitate.

Mr Macgregor found the urea passed daily in a well-marked case of jaundice to be 217 grains. Specific gravity of urine 1·012. In another case, urea, 325 grains, specific gravity of urine, 1·020. In a third, urea, 315 grains, specific gravity of urine, 1·012.

6. In general *dropsy* or *anasarca*, the serum of the blood mixes with the urine, and renders it albuminous. In such cases it becomes milky when heated or when mixed with acids. If we add acetic acid, and then drop in prussiate of potash, a white precipitate falls. It precipitates also with corrosive sublimate.

* Schweigger's Jour. l. 205. † Ibid. p. 206.
‡ Phil. Trans. 1797, p. 386.

In dropsy from diseased liver, the urine in general is not albuminous, but it is scanty, high-coloured, and deposits a pink sediment.

As the quantity of albumen increases in dropsical urine, that of the urea diminishes, and is said even to disappear; though I have never examined any dropsical urine in which I was not able to find traces of urea.

7. During hysterical paroxysms the urine usually flows abundantly, it is limpid and colourless, though the colouring matter is not absolutely wanting. For when sufficiently concentrated the usual colour of urine begins to be perceptible; and I have always been able to detect in it the presence of urea; though the quantity is certainly much smaller than usual.

It is well known that the most usual medicine administered during chlorosis is protoxide of iron, prepared in various ways. It has been generally admitted by physiologists, that the iron passes into the system, and is employed in completing the globules of the blood which are defective in that disease, and that the surplus is carried off by the urine. But M. Gelis has shown that this plausible explanation is not well founded. He examined the urine of 80 patients labouring under chlorosis, and all under a course of iron preparations; but in none of these urines could the least trace of iron be detected.*

8. In *syphilis* the urine of a man who had been taking mercury by means of the blue ointment, was found by Dr Cantu to contain mercury. He mixed the precipitate from the urine with carbonate of potash and charcoal powder, and distilled at a red heat, globules of mercury were found in the receiver.† Chevallier, who examined the urine of a syphilitic patient while under a course of mercury, found it milky, of a slightly ammoniacal smell, and giving out ammonia and sulphuretted hydrogen. It was mixed with clots of blood, and of course contained all the substances that exist in that complicated liquid. The constituents of urine could also be detected.‡

9. The urine in a *catarrhus vesicæ* was examined by Fromherz and Gugert.§ It was whitish and very muddy, had an acid re-

* Jour. de Pharm. xxvii. 261.
† Ann. de Chim. et de Phys. xxvii. 335.
‡ Jour. de Chim. Med. i. 179.
§ Schweigger's Jour. l. 204.

action, and deposited a sediment consisting entirely of mucus of the bladder, They could find no trace of uric acid; but the other constituents were present in their usual proportions.

I have seen cases seemingly connected with catarrhus vesicæ in which the urine when voided was usually alkaline and muddy, and had an excessively disagreeable smell. But I never had an opportunity of examining such urine chemically. The urine could be completely evacuated only by means of the catheter.

When urine contains pus it is muddy or soon becomes so. It gradually deposits a sediment and becomes transparent. The sediment is white, opaque, and in clots. When treated with ether it gives out a great deal of fatty matter. When mixed with ammonia it becomes gelatinous. It burns, when dried, with a vivid flame. The urine when heated deposits albumen. This urinary portion will be alkaline if the pus exists in considerable quantity.

When pus is mixed with urine, the conversion of the urea into carbonate of ammonia is hastened.

10. But the disease in which the urine changes its nature most remarkably is *diabetes.* There are two species of this disease; namely, *diabetes insipidus* and *diabetes mellitus.* In the first the urine is nearly tasteless; in the second, it is sweet, containing a considerable quantity of sugar of grapes.

In diabetes insipidus the quantity of urine is greatly augmented; but it is colourless and tasteless. The specific gravity of the urine is low. In two cases treated in the Glasgow Infirmary, Mr Macgregor found the specific gravity to vary from 1·003 to 1·005. The urea voided daily in these two cases was 310 and 400 grains. Mr Macgregor does not mention the quantity of urine voided daily. Opium was found to palliate but not to cure this disease.*

Diabetes mellitus (judging from the number of hospital cases), seems to be a more common disease in Glasgow than in London. The average number of diabetic patients admitted into the Glasgow Infirmary yearly is 5. In this disease the quantity of urine is greatly augmented, sometimes amounting to 70 lbs avoirdupois in 24 hours. Mr Macgregor mentions a case in the Glasgow

* Macgregor's Experimental Enquiry, p. 11.

Infirmary, in which the quantity of urine voided daily amounted to 45 lbs., while its specific gravity was 1·054. The quantity of sugar which it contains increases with the specific gravity. The following table, drawn up by Dr Henry,* from his own experiments, show the quantity of solid matter contained in diabetes urine of different specific gravities.

Specific gravity.	Solid extract in a wine pint in grs.	Specific gravity.	Solid extract in a wine pint in grs.
1·020,	382·4	1·036,	689·6
1·021,	401·6	1·037,	708·8
1·022,	420·8	1·038,	728·0
1·023,	440·0	1·039,	747·2
1·024,	459·2	1·040,	766·4
1·025,	478·4	1·041,	785·6
1.026,	497·6	7·042,	804·8
1·027,	516·8	1·043,	824·0
1·028,	536·0	1·044,	843·2
1·029,	555·2	1·045	852·4
1·030,	574·4	1·046	881·6
1·031,	593·6	1·047,	900·8
1·032,	612·8	1·048,	920·0
1·033,	632·0	1·049	939·2
1·034,	651·2	1·050	958·4
1·035,	670·4		

In this disease the thirst is insatiable, and the appetite voracious. Yet the egesta in general are less than the ingesta. The following two cases, which illustrate this, are related by Mr Macgregor in his *Experimental Enquiry*.

1. A boy, 16 years of age, weighing 5 stones and 2 lbs. Specific gravity of urine 1·035. The following table shows the ingesta and egesta from the 6th December to the 31st December inclusive:

Date. 1834.	Ingesta. Liquid. lbs.	Ingesta. Solid. lbs. oz.	Ingesta. Total. lbs. oz.	Egesta. Liquid. lbs. oz.	Egesta. Solid. lbs. oz.	Egesta. Total. lbs. oz.
Dec. 6	13	3 0	16 0	18 0	1 0	19 0
7	6	3 0	9 0	10 0	0 5	10 5
8	12	2 4	14 4	11 6	1 4	12 10
9	15	3 1	18 1	18 0	1 8	19 8
10	10	1 10	11 10	17 6	0 0	17 6
11	6	1 9	7 9	10 0	0 4	10 4
12	11	1 12	12 12	15 0	0 8	15 8

* Annals of Philosophy, i. 29.

Date.	Ingesta.					Egesta.					
	Liquid.	Solid.		Total.		Liquid.		Solid.		Total.	
1834.	lbs.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
Dec. 13	8	2	9	10	9	10	0	0	8	10	8
14	16	3	2	19	2	15	0	2	3	17	3
15	10	2	9	12	9	15	0	0	4	15	4
16	13	2	9	15	9	15	0	0	0	15	0
17	10	1	9	11	9	10	0	0	0	10	0
18	8	2	0	10	0	10	0	2	1	12	1
19	8	2	0	10	0	10	0	2	11	12	11
20	9	2	7	11	7	8	6	1	3	9	9
21	9	2	4	11	4	7	6	0	0	7	6
22	9	2	9	11	4	7	6	1	4	8	10
23	6	1	13	7	13	7	6	1	6	8	12
24	6	2	9	8	9	7	6	2	6	9	12
25	6	3	1	9	1	10	0	0	0	10	0
26	12	3	1	15	1	10	0	0	4	10	4
27	12	3	1	15	1	15	0	0	0	15	0
28	11	3	1	14	1	12	6	0	4	12	10
29	11	3	1	14	1	15	0	0	3	15	3
30	11	2	9	11	9	17	0	0	0	17	0
31	12	2	7	14	7	20	0	0	8	20	8
		Total,		330	5					344	10

The average quantity of food and drink per day was 12 lbs. 11 oz. while that of the egesta was 13 lbs. 4 oz. so that the latter exceeded the former by the daily average of 9 oz. With a view to introduce as much azote as possible into the system, a scruple of nitrate of ammonia was administered thrice a day, and continued till the 19th, at which date the thirst was considerably diminished, and the quantity of urine much less, probably in consequence of the animal food to which his diet was restricted.

On the 22d December six drops of creosote were ordered to be taken in the course of the day. The dose was gradually augmented, and on the 10th of January amounted to sixty drops; but it irritated the stomach to such a degree that it was found necessary to stop it.

Date.	Ingesta.					Egesta.					
	Liquid.	Solid.		Total.		Liquid.		Solid.		Total.	
1835.	lbs.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
Jan. 1	7	2	0	9	0	10	0	0	4	10	4
2	11	2	1	13	1	10	1	2	0	12	1
3	13	1	0	14	0	15	6	2	6	17	12
4	10	2	0	12	0	13	0	0	0	13	0
5	11	2	0	13	0	10	0	1	0	11	0
6	6	1	6	7	6	12	3	0	0	12	3
7	9	2	6	11	6	12	0	0	0	12	0
8	6	2	6	8	6	10	2	0	0	10	2
9	10	2	9	12	9	10	0	1	4	11	4

Date. 1835.	Ingesta. Liquid. lbs.	Solid. lbs. oz.		Total. lbs. oz.		Egesta. Liquid. lbs. oz.		Solid. lbs. oz.		Total. lbs. oz.	
Jan. 10	10	2	9	12	9	10	4	0	0	10	4
11	10	2	9	12	9	12	7	0	0	12	7
12	9	2	1	11	1	11	0	1	0	12	0
13	7	2	2	9	2	12	3	0	0	12	3
14	10	2	2	12	2	10	0	0	0	10	0
15	5	1	9	6	9	5	7	1	11	7	2
16	6	1	9	7	9	5	7	0	0	5	7
17	6	1	9	7	9	5	7	0	0	5	7
18	6	1	9	7	9	4	0	0	0	4	0
19	4	1	9	5	9	4	0	0	0	4	0
20	4	1	9	5	9	3	7	1	0	4	7
21	4	1	9	5	9	3	[illegible]	0	0	3	7
22	3	1	9	4	9	3	7	1	0	4	7
23	4	1	9	5	9	3	0	0	0	3	0
24	3	1	9	4	9	2	7	0	0	2	7
25	5	1	9	6	9	4	0	0	0	4	0
26	5	1	9	6	9	2	7	0	0	2	7
27	4	1	9	5	9	2	6	1	1	2	6
28	3	1	9	4	9	2	7	0	0	2	7
29	3	1	9	4	9	2	6	0	8	2	14
30	2	1	9	3	9	2	6	1	0	3	1
31	2	1	9	3	9	2	1	0	0	2	1
		Total,		258						233	10

On the 16th of January opium was ordered in grain doses thrice a-day. After a few days the dose was gradually increased, and on the 31st of January the quantity amounted to half a-drachm daily. The urine was now strongly alkaline, containing carbonate of ammonia, but no urea. It is probable that the urea had been decomposed, and carbonate of ammonia formed before the urine was voided. The patient sweated copiously, and his weight was 2 lbs. greater than when he entered the hospital. The thirst was greatly diminished, and the ingesta exceeded the egesta by about a tenth.

Date. 1835.	Ingesta. Liquid. lbs.	Solid. lbs. oz.		Total. lbs. oz.		Egesta. Liquid. lbs. oz.		Solid. lbs. oz.		Total. lbs. oz.	
Feb. 1	3	1	9	4	9	2	0	0	0	2	0
2	3	0	2	3	2	1	0	0	0	1	0
3	2	0	9	2	9	1	0	0	0	1	0
4	3	0	9	3	9	1	0	0	0	1	0
5	2	0	9	2	9	1	0	0	2	1	2
6	2	1	9	3	9	1	0	0	4	1	4
7	3	1	9	4	9	2	2	0	0	2	2
8	4	1	9	5	9	2	2	0	0	2	2
9	3	1	9	4	9	2	4	0	4	2	8
10	2	0	9	2	9	2	0	1	4	3	4
11	2	1	9	3	9	2	1	0	0	2	1

Date 1835.	Ingesta. Liquid. lbs.	Solid. lbs.	oz.	Total. lbs.	oz	Egesta. Liquid. lbs.	oz.	Solid. lbs.	oz.	Total. lbs.	oz.
Feb. 12	2	1	9	3	9	2	6	0	0	2	6
13	2	1	9	3	9	2	0	0	0	2	0
14	2	1	9	3	9	2	1	0	4	2	5
15	3	1	9	4	9	2	1	0	0	2	1
16	2	0	0	2	0	2	8	2	8	5	0
17	3	1	9	4	9	2	0	0	0	2	0
18	3	0	9	3	9	2	0	0	4	2	4
19	3	1	2	4	2	2	3	0	0	2	3
20	3	1	2	4	2	3	0	0	0	3	0
21	3	1	9	4	9	3	1	0	0	3	1
22	3	1	9	4	9	3	4	0	0	3	4
23	3	1	9	4	9	3	5	0	0	3	5
24	4	1	2	5	2	3	0	0	2	3	2
25	6	1	9	7	9	3	0	0	1	3	1
26	6	2	9	8	9	5	0	0	1	5	1
27	6	2	2	8	2	9	0	0	4	9	4
28	6	1	9	7	9	9	0	0	0	9	0
		Total,		129	4					83	4

The opium was gradually increased, and on the 24th of February amounted to a drachm in 24 hours. The symptoms which usually attend opium eating made their appearance. Though the quantity of urine was so greatly diminished, its specific gravity was as high as 1·032. It did not taste sweet, and yet it contained a good deal of sugar. The urea was so abundant, that when nitric acid was added, crystals of nitrate of urea appeared within ten minutes. The opium was discontinued on the three last days of the month. The thirst and quantity of urine immediately increased.

Date. 1835.	Ingesta. Liquid. lbs.	Solid. lbs.	oz.	Total. lbs.	oz.	Egesta. Liquid. lbs.	oz.	Solid. lbs.	oz.	Total. lbs.	oz.
March 1	5	2	2	7	2	5	0	0	0	5	0
2	6	1	9	7	9	4	0	1	2	5	2
3	3	1	2	4	2	2	0	0	0	2	0
4	5	1	2	6	2	4	1	0	0	4	1
5	4	1	9	5	9	2	6	2	8	4	14
6	3	1	9	4	9	6	2	0	0	6	2
7	3	1	9	4	9	4	0	0	0	4	0
8	3	1	9	4	9	4	1	1	3	5	4
9	4	1	2	5	2	2	3	0	0	2	3
10	5	1	9	6	9	2	6	0	4	2	10
11	5	1	9	6	9	2	6	0	6	2	12
12	5	1	9	6	9	2	2	0	0	2	2
13	4	1	9	5	9	2	1	0	0	2	1
14	3	1	9	4	9	2	8	1	2	3	10
15	3	1	9	4	9	2	9	0	0	2	9
16	5	1	9	6	9	2	3	0	8	2	11
17	5	1	9	6	9	3	6	0	0	3	6

Date. 1834.	Ingesta. Liquid. lbs.	Solid. lbs. oz.	Total. lbs. oz.	Egesta. Liquid. lbs. oz.	Solid. lbs. oz.	Total. lbs. oz.
Mar. 18	6	2 1	8 1	4 0	0 3	4 3
19	7	2 1	9 1	3 6	0 0	3 6
20	7	1 9	8 9	3 4	0 6	3 10
21	7	1 9	8 9	4 2	0 0	4 2
22		1 9	8 9	5 0	0 4	5 4
23	7	1 9	8 9	6 0	0 0	6 0
24	7	1 9	8 9	6 4	0 6	6 10
25		1 9	8 9	4 6	0 0	4 6
26	6	1 9	7 9	7 0	0 0	7 0
27	6	2 6	8 6	7 6	1 5	8 11
28	6	2 6	8 6	7 4	0 0	7 4
29	7	2 6	9 6	7 9	0 2	7 11
30	7	2 6	9 6	8 0	0 0	8 0
31	7	2 6	9 6	8 2	0 0	8 2
	Total,		220 0	Total,		148 0

Towards the end of the month of March the opium was discontinued, and this was followed by a return of the original symptoms. The patient was dismissed shortly after. The quantity of urine was daily 8 lbs. It had a sweetish taste, and fermented readily with yeast. At the end of March his weight was 5 stones and 3 lbs.

In the second case given by Mr Macgregor, the symptoms and treatment were nearly the same. It is unnecessary, therefore, to state it at length.

Mr Macgregor found urea in diabetic urine to fully as great an amount as in healthy urine. One patient passed daily 14·65 lbs. of urine of specific gravity 1·039. It contained 1013·5 grains of urea. Another passed 30 lbs. of urine of specific gravity 1·045. This urine contained 945 grains of urea. A third passed daily 40 lbs. of urine of specific gravity 1·034, and containing 810 grains of urea. A fourth passed 25 lbs. of urine of specific gravity 1·050, and containing 512·5 grains of urea. Now the greatest quantity of urea passed in twenty-four hours in the tables of Lecanu given above, and containing 93 cases, was 501·06 grains.

The sugar which exists in such quantity in the urine of diabetic patients is not generated by the kidneys, but by the organs of digestion. Mr Macgregor found it abundantly in the blood,*

* Vauquelin had long ago examined the blood of a diabetic patient without finding any sugar in it. (Jour. de Physiologie, iv. 257.) This also had been done by Dr Wollaston. The method employed by these chemists had not been sufficiently delicate.

and also in the saliva, sweat, and stools of diabetic patients. The abnormal state of the digestive organs gives origin to the formation of this sugar. No medical treatment hitherto tried has been capable of removing the disease. Animal food seems to diminish the thirst and urine by bringing on nausea. Opium palliates but does not remove the disease. It is obvious from the facts above stated that there is no want of urea in diabetic urine. Hence it is very probable that the introduction of urea into the stomach of diabetic patients, as has been proposed by some medical men in France, would not contribute to remove the disease.

11. *Urine during cramp of the stomach.*—This urine was examined by M. L. Gmelin.* It was clear, brown in mass, but yellow in thin layers. With muriatic acid it formed a brown mixture, with much nitric acid a clear red mixture, with a small quantity of that acid a violet-coloured precipitate. This precipitate was chiefly uric acid. On standing twenty-four hours the urine deposited a rose-red sediment. The urine contained uric acid, purpuric acid, and altered choleic acid.

12. *Intoxicating urine.*—It has been long known that the Tartars make an intoxicating liquor by infusing the *Agaricus muscarius* in *koumiss*, or fermented mare's milk; and that the intoxicating properties of this agaric pass into the urine of those who have taken it into the stomach. Langsdorf, in his travels among the *Koræken*, has remarked that the urine is even more intoxicating than the prepared koumiss itself. It is much sought after by other persons, who intoxicate themselves by drinking it. Indeed, such is the persistence of this intoxicating quality, that urine voided by five or six individuals in succession still retains it.†

13. In certain cases females, and sometimes males, have been observed to pass urine which had the appearance of milk. On standing a cream was formed on its surface, and it was found to contain a notable proportion of casein.‡

14. Medical men have repeatedly made mention of *blue* urine, deriving its colour from a blue substance held in suspension in it, quite different from Prussian blue. Gornier and Delens found this blue colouring matter a little soluble in water. Neither acids nor alkalies alter its colour; but nitric acid destroys it.§

* Ann. der Pharm. xxvi. 359. † Jour. de Pharmacie, xii. 477.
‡ Caballe, Ann. de Chim. iv. 64. § Jour Gener. de Medecine, lxxii. 174.

Braconnot met with a case of blue urine passed by a girl of fifteen years of age, enjoying pretty good health, though subject to stomach complaints.* During a paroxysm of pain in the stomach she vomited and voided urine. Both liquids had so deep a blue colour that they appeared almost black. The blue pigment which this urine contained had neither taste nor smell. It was in a state of very minute division, and had a deeper colour than Prussian blue. When heated it gave out carbonate of ammonia and an empyreumatic oil. It was slightly soluble in water and in boiling alcohol. The alcohol assumed a green colour, and deposited on cooling a small quantity of very deep blue pigment, almost crystalline. When the alcohol evaporated the blue pigment remained, and dissolved in acids with the exception of a little fatty matter. The blue pigment is soluble in all acids, even the oxalic and gallic, and when so dissolved becomes red. When a saturated solution of this colouring matter in dilute sulphuric acid is evaporated, we obtain a carmine-red residue, which becomes brown when dissolved in water, but resumes its red colour when the water is evaporated off. The blue matter is slightly soluble in acetic acid. The solution is brownish-yellow, but when the acid is driven off, the blue colouring matter is left unaltered. When the red acid solutions are saturated with an alkali, the colouring matter precipitates with its original blue colour. This blue matter is scarcely soluble in caustic potash, and not at all in the carbonate of potash.

The urine from which this blue matter had separated let fall when heated an additional quantity of this blue matter of so deep a shade that it appeared black, but possessed the properties of the original blue pigment. Braconnot considers this blue sediment as a salifiable base, and has distinguished it by the name of *cyanurin*.

Marx made some experiments on a blue-coloured urine passed by Dr Wollring at Gottingen.† He analyzed the sediment, and states its constituents as follows:

Blue colouring matter,	29·09
Uric acid,	46·80
Earthy phosphates,	18·19
Mucus,	5·92
	100·

* Ann. de Chim. et de Phys. xxix. 252. † Schweigger's Jour. xlvii. 487.

The characters of the blue matter differed somewhat from those described by Braconnot. It was soluble in alcohol, and when the solution was evaporated, the blue sediment remained without showing the least tendency to crystallization. It was soluble, also, in boiling ether. Concentrated sulphuric acid dissolved it and assumed a blue colour, but muriatic acid did not act upon it. Nitric acid, when heated, destroyed it, and converted it into Welter's *bitter principle.* It was insoluble in caustic alkalies and their carbonates. When burnt, it left a little phosphate of lime.

15. Urine is sometimes mixed with blood. If the quantity of blood be considerable, its presence is easily recognized by the red colour. The globules of blood do not dissolve in urine. They fall to the bottom, and may be easily distinguished by examining the sediment through the microscope.

Urine containing blood always holds in solution some albumen, which coagulates when the urine is heated or mixed with nitric acid. Such urine is always alkaline, unless the quantity of blood be very small. The globules of blood in urine assume an irregular form, and when treated with ammonia or acetic acid dissolve completely. M. Lecanu has given the following method of detecting minute quantities of blood in urine :*

If the urine be ammoniacal it is neutralized by nitric acid, and raised to the boiling temperature. The albumen coagulates and falls to the bottom, carrying with it the globules of the blood. The deposit, is collected on a filter and washed first with water, and then with alcohol. It is then introduced into a matrass with alcohol of 0·842, slightly acidulated with sulphuric acid, and the liquid raised to the boiling temperature. The deposit, which was at first reddish-brown, becomes colourless, while the alcohol assumes a brownish colour, which a slight addition of ammonia changes to red. The alcoholic solution being concentrated leaves the colouring matter in the state of a black resinous-looking matter, soluble in acetic ether and ammoniacal alcohol, to which it gives a red colour, as soon as the alcohol and ammonia are evaporated. If we calcine this matter, there remains a red ash, soluble in muriatic acid, and the solution strikes a blue with prussiate of potash.

16. Dr Marcet, in the twelfth volume of the Medico-Chirurgical Transactions, described a singular variety of urine, which

* Jour. de Pharm. xxvi. 206.

became *black* soon after it was passed. A portion of this urine was examined by Dr Prout, who gave the following account of it:*

The residue remaining after the urine is evaporated to dryness contains no uric acid, and no urea can be detected in it by the usual tests. Although the addition of dilute acids produced no immediate change of colour in this urine, yet, on standing some time, a *black* precipitate slowly subsided, leaving the supernatant fluid transparent and but slightly coloured.

The black precipitate was nearly insoluble in water and alcohol, whether hot or cold. It dissolved in concentrated sulphuric and nitric acids, forming a deep brownish-black solution; but on adding water the black substance precipitated unaltered. It dissolved readily in the fixed alkalies, and in their carbonates; but acids precipitated it unaltered. When ammonia was employed as a solvent, and the excess driven off by evaporating to dryness, a deep-brown matter remained, composed of the black matter and ammonia. This compound was very soluble in water, and when heated with caustic potash, gave out the smell of ammonia. It would not crystallize. From the aqueous solution of this brown matter chloride of barium and nitrate of silver threw down copious brown precipitates; as did also protonitrate of mercury and nitrate of lead. Corrosive sublimate produced no immediate precipitate, and that obtained from acetate of zinc was of a pale-brown colour.

From these experiments Dr Prout inferred that the urine owed its black colour to a compound of the black matter with ammonia. The black matter he considers as an acid, which he distinguishes by the name of *melanic acid*. No experiments have been made to determine the nature of this acid, or the relation in which it stands to uric acid.

17. Some very cruel experiments were made upon dogs by M. Collard de Martigny. He starved the poor animals to death. In the urine of a dog thus treated he could detect no urea.† The same remark was made by Magendie with respect to the urine of dogs fed on sugar, gum, or olive oil, which in fact died of starvation.‡

* Annals of Philosophy, (2d series), iv. 71.

† Jour. de Physiologie, viii. 157. ‡ Ibid. ii. 487.

But Lassaigne found urea in the blood of a madman who had fasted during eighteen days.*

According to Martigny, the proportion of albumen in blood increases by abstinence, while that of fibrin diminishes, and the quantity of blood is constantly diminishing as long as abstinence is continued.†

18. Donné observes that, after eating sorrel, the urine was filled with minute crystals of oxalate of lime.‡

19. Viscid urine.

MM. Cap and Henry examined a urine to which they gave that name. It was acid when voided, but soon became alkaline. It had a light-yellow colour, and was muddy, and a white magma occupied the greatest part of the liquid, floating by the slightest agitation, and depositing itself slowly. A scanty gray sediment was at the bottom of the vessel. The viscid magma was separated by the filter. The urine filtered had a specific gravity of 1·00691. It was composed of,

Water,	98·12
Urea,	0·40
Albumen,	0·17
Mucus,	0·50
Chlorides of sodium, potassium, ammonium, Urate of ammonia, Phosphates of soda, ammonia, lime, magnesia,	0·81
Sulphate of soda trace.	
Lactate of ammonia trace.	
	100·00

The viscid magma consisted of fibrin, albumen, and spermatin.§

Such are the characters and constitution of human urine, and such the changes produced in it by disease, as far as the subject has been investigated. Much less progress has been made in the investigation of the urine of the inferior animals. The following are the principal facts on this prolific subject that have been hitherto ascertained:

I. The urine of carnivorous animals is acid, and usually contains salts of ammonia; the urine of graminivorous animals is alkaline, and contains carbonates, particularly carbonate of lime.

* Jour. de Chimie Medicale, 1825.
† Jour. de Physiol. viii. 165, 169.
‡ Comptes Rendus, viii. 805.
§ Jour. de Pharm. xxiii. 329.

II. The urine of the monkey, according to Coindet, has a greenish-yellow colour, and its specific gravity varies from 1·0045 to 1·0108. It contains a good deal of salts of sulphuric and phosphoric acids, a great deal of salts of potash, but no uric acid.*

III. The urine of the dog,† according to Tiedemann and Gmelin, has a yellowish or greenish-brown colour. It has an acid reaction; becomes reddish-yellow, and then green when mixed with muriatic acid. When mixed with nitric acid, much uric acid fell, and the urine became green, then blue, and finally dark-red.‡ These phenomena show clearly that the urine of the dog examined contained bile.

IV. The urine of the horse has usually an amber colour. When voided it is sometimes transparent, sometimes muddy, and it soon deposits a white precipitate, consisting chiefly of carbonate of lime. Its specific gravity, according to Fourcroy and Vauquelin, varies from 1·03 to 1·05. The specific gravity of a specimen examined by Dr Prout was 1·0293.§ That of a horse experimented on by Boussingault, 1·064.‖ The average quantity voided in twenty-four hours was only 2·928 lbs. He found in it a greater quantity of urea than in human urine. It was announced many years ago by Fourcroy and Vauquelin, that the urine of the horse contains benzoic acid. But Liebig has shown that the acid contained in the urine of the horse is not the benzoic, but another acid containing peculiar properties, to which he has given the name of *hippuric*,¶ and which has been described in a former part of this work.**

The constituents of the urine of the horse, as determined by Fourcroy and Vauquelin, are the following:

Water and mucus,	94·
Carbonate of lime,	1·1
Carbonate of soda,	0·9
Hippurate of soda,	2·4
Chloride of potassium,	0·9
Urea,	0·7
	100·0††

* Biblioth. Univer. xxx. 492.

† The gall-ducts of this animal were tied.

‡ On Digestion, ii. 4.

§ Annals of Philosophy, xvi. 150.

‖ Ann. de Chim. et de Phys. lxxi. 128.

¶ Ibid. xliii. 188.

** See Chemistry of Vegetables, p. 46.

†† Mem. de l'Institut. ii. 431.

Mr Brande, about the year 1806, made some experiments on the urine of the horse, which are stated by Mr Hatchett in a letter to Sir Everard Home.* He extracted from that urine the following salts:

Carbonate of lime.	Common salt.
Carbonate of soda.	Hippurate of soda.
Sulphate of soda.	Phosphate of lime.

These saline contents constituted about one-eighth of the weight of the urine. So that the water, according to this estimate, amounts only to 87·5 per cent. Chevreul examined the urine of the horse in 1808, expressly to ascertain whether it contained phosphate of lime, as stated by Brande.† He could find none; but detected magnesia and sulphate of potash.

V. The urine of the ass was examined by Mr Brande in 1806.‡ It was transparent and colourless, gave a green colour to the syrup of violets, but no carbonate of lime was deposited when the urine was left at rest. According to Brande, it contained urea, more phosphate of lime than the urine of the horse, carbonate of soda, sulphate of soda, common salt, and probably chloride of potassium. It contained no ammonia.

VI. The urine of the cow has a strong resemblance to that of the horse. It has nearly the same colour and the same mucilaginous consistence. It tinges syrup of violets green, and deposits a mucous matter. On standing, small crystals are formed on its surfaces. The quantity voided in 24 hours by a cow giving milk, was found by Boussingault to be 18·13 lbs., and the milk 18·7 lbs. The water drank in 24 hours was 132·282 lbs. The specific gravity of the urine was 1·035.§ It contains, according to Rouelle,

Carbonate of potash.	Urea.
Sulphate of potash.	Hippuric acid?
Chloride of potassium.	

Mr Brande examined this urine in 1806,‖ and found its constituents,

* Phil. Trans. 1806, p. 380.
† Ann. de Chim. lxvii. 303.
‡ Phil. Trans. 1806, p. 380.
§ Ann. de Chim. et de Phys. lxxi. 113.
‖ Phil. Trans. 1806, p. 378.

Water,	65
Phosphate of lime,	3
Chloride of potassium, } Sal-ammoniac, }	15
Sulphate of potash,	6
Carbonate of potash, } Carbonate of ammonia, }	4
Urea,	4
	97

He obtained also a quantity of benzoic acid, (probably hippuric acid,) but considers it as proved, that this acid was formed during the process to which the urine was subjected.

VII. The urine of the camel has been examined by Rouelle, Brande, and Chevreul. The smell resembles that of the cow. Its colour is that of beer; it is not mucilaginous, and does not deposit carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acids like the urine of the horse and cow. Rouelle* obtained from it,

Carbonate of potash. Chloride of potassium.
Sulphate of potash. Urea.

Mr Brande† made a set of experiments on the urine of the camel, at the request of Sir Everard Home, and obtained,

Water,	75
Phosphate of lime, } Sal-ammoniac, } Sulphate of potash, } Urate of potash, } Carbonate of potash, }	6
Common salt,	8
Urea,	6
	95

Chevreul examined the urine of the camel on purpose to ascertain whether the phosphate of lime, stated by Brande as a constituent, really existed in that urine.‡ He could find no traces of it, but extracted from the urine of the camel the following substances:

* Jour. de Med. xl. † Phil. Trans. 1806, p. 376.
‡ Ann. de Chim. lxvii. 294.

Albumen.
Carbonate of lime.
Carbonate of magnesia.
Silica.
Trace of sulphate of lime.
Trace of iron.
Carbonate of ammonia.
Chloride of potassium.
A little sulphate of soda.
Much sulphate of potash.
A little carbonate of potash.
Hippuric acid?
Urea.
A brown oil, having a strong smell.

VIII. The urine of the sow was subjected to chemical analysis in 1819, by M. Lassaigne.* It is transparent, slightly yellow, without smell, and having a disagreeable, but not saline, taste. The following were the substances extracted from this urine by M. Lassaigne:

Urea.
Sal-ammoniac.
Chloride of potassium.
Common salt.
Sulphate of potash.
A little sulphate of soda.
Trace of sulphate and carbonate of lime.

IX. The urine of the rabbit was examined by Vauquelin.† When exposed to the air it becomes milky, and deposits carbonate of lime. It gives a green colour to syrup of violets and effervesces with acids. Vauquelin detected in it the following substances:

Carbonate of lime.
Carbonate of magnesia.
Carbonate of potash.
Sulphate of potash.
Sulphate of lime.
Chloride of potassium.
Urea.
Mucus.
Sulphur.

X. The urine of the guinea pig was examined also by Vauquelin; though the quantity subjected to analysis was too small to enable him to make a detailed examination. It became turbid, and deposited carbonate of lime on cooling, gave a green colour to syrup of violets, and was found to contain carbonate of potash and chloride of potassium; but neither phosphate nor uric acid could be detected in it.‡

XI. The urine of the rhinoceros was examined by M. Vogel in 1817.§ It was muddy, and let fall on cooling a great quantity of an ochre-yellow matter. Twenty pounds of the urine

* Jour. de Pharmacie, viii. 174.
† Fourcroy's *General System of Chemical Knowledge*, x. 265.
‡ Ibid. p. 267.
§ Schweigger's Jour. xix. 156.

yielded 6 ounces and 5 drachms of this deposit. It consisted of carbonates of lime and magnesia with a little iron and silica, and a small quantity of an animal substance containing azote.

The smell of the urine was peculiar, and had some resemblance to that of bruised ants. It effervesced strongly with acids. Its colour after filtration was dark-yellow. Even after filtration it continued to effervesce on the addition of acids. It very slightly reddened litmus-paper. When boiled it became brown, and ceased to act on litmus-paper, and hardly became muddy when mixed with oxalate of ammonia.

This urine contained,

Mucus.	Bicarbonate of lime.
Urea.	Sulphate of lime.
Sulphuretted hydrogen.	Carbonate of magnesia.
Carbonate of ammonia.	Silica.
Hippurate of potash ?	Iron.
Chloride of potassium.	

XII. The urine of the elephant was also examined by M. Vogel.* Its colour was the same as that of the rhinoceros but not so dark. It gave a green colour to syrup of violets, deposited less sediment on cooling than the urine of the rhinoceros, and gave out when heated less carbonic acid and sulphuretted hydrogen. Its constituents were similar to those of the preceding urine. But it contained more mucus, urea, and carbonate of ammonia, and less carbonate of lime, and carbonate of magnesia, and no hippuric acid.

XIII. The urine of the beaver has a striking resemblance to that of herbivorous animals in general. Vauquelin † extracted from it the following substances:

Mucus.	Sulphate of potash.
Urea.	Chlorides of potassium and sodium.
Hippurate of potash ?	Colouring matter.
Carbonates of lime and magnesia.	Trace of iron.
Acetate of magnesia.	

XIV. The urine of the lion, tiger, hyæna, and leopard, when quite fresh, reddened litmus-paper; but speedily becomes neutral and then alkaline.‡ It contains uric acid. Vauquelin made

* Schweigger's Jour. xix. p. 162. † Ann. de Chim. lxxxii. 201.
‡ Stromeyer, Edin. Jour. of Science, xviii. 356.

some experiments upon the urine of the lion and the tiger, and obtained results differing from those of Stromeyer.* According to him it is alkaline at the time of its emission. It contains, he says, a quantity of ammonia; but no uric acid nor phosphate of lime. Vauquelin obtained from it the following substances:

Mucus.	Sal-ammoniac.
Urea.	Trace of phosphate of lime.
Phosphate of soda.	Much sulphate of potash.
Phosphate of ammonia.	Trace of common salt.

XV. The urine of fowls, as was first ascertained by Dr Wollaston, consists chiefly of uric acid. It seems to be combined with ammonia, and is mixed with a good deal of animal matter.

XVI. The urine (if that name can be given to a solid excrementitious substance) of the Boa constrictor was found by Dr Prout to consist almost entirely of urate of ammonia. This fact being communicated to Dr John Davy while in Ceylon, about the year 1817, he was induced to examine the excrements of different species of serpents.† When thrown out it has a butyraceous consistence, but becomes hard by exposure to the air. He found it to consist chiefly of uric acid, probably in the state of urate of ammonia. The urinary matter of lizards was similar. That of the alligator, besides uric acid, contains a large portion of carbonate and phosphate of lime. The urine of turtles was liquid, containing flakes of uric acid, and holding in solution a little mucus and common salt, but no sensible portion of urea.

Some experiments on the urine of lizards (*Lacerta agilis, Seps viridis, varius, terrestris, sericeus, cæruleus,* &c.) had been made by M. Schriebers as early as 1813.‡ He found it to consist of,

Uric acid, .	94
Ammonia, .	2
Phosphate of lime,	3·33
	99·33

So that he preceded Dr Davy, and probably also Dr Prout, in this curious investigation.

* Ann. de Chim. lxxxii. 198. † Phil. Trans. 1818, p. 303.

‡ Gilbert's Annalen, xliii. 83.

CHAPTER XIII.

OF SEMEN.

The liquor secreted in the testes of males, and destined for the impregnation of the female, is known by the name of *semen*. The human semen and the *milt* of fresh-water fishes alone have hitherto been subjected to a chemical examination. Nothing is known concerning the semen of other animals. Vauquelin published an analysis of human semen in 1791.* Jordan made some experiments on it in 1801.† Dr John also examined it, though I have never seen the paper which he published on the subject. Berzelius likewise has subjected semen to a chemical examination.‡

I. Semen, when newly ejected, is evidently a mixture of two different substances. The one, fluid and milky, which is supposed to be secreted by the prostate gland; the other, which is considered as the secretion of the testes or the true semen, is a thick mucilaginous substance, in which numerous white filaments may be discovered. These filaments constitute a peculiar animal principle, which has been distinguished by the name of *spermatin*.

Semen has a slight but unpleasant smell, an acrid irritating taste, and its specific gravity is higher than that of water. When rubbed in a mortar, it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It changes syrup of violets to green, from the uncombined *soda* which it contains.

As the liquid cools, the mucilaginous part becomes thready, and acquires greater consistency, but in about twenty minutes after its emission, the whole becomes liquid. This liquefaction is not owing to the absorption of moisture, for it loses instead of gaining weight; nor to the action of the air, for it takes place equally in vacuo.

Semen is insoluble in water before this liquefaction, but afterwards it dissolves readily in it. When alcohol or chlorine is added to this solution, white flocks separate. Alkalies readily dissolve the semen, and it is soluble in concentrated sulphuric acid,

* Ann. de Chim. ix. 64. † Crell's Annalen, 1801, i. 461.

‡ Traité de Chimie, vii. 558.

and in nitric acid when assisted by heat, but acetic acid only dissolves it partially.

Lime disengages no ammonia from fresh semen, but after that fluid has remained for some time in a moist and warm atmosphere, lime separates a great quantity from it. Hence ammonia is formed during the exposure of semen to the air.*

When chlorine is added to semen, a number of white flocks separate, and the chlorine loses its smell. If the quantity of chlorine be considerable, the semen assumes a yellow colour.

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a transparent pellicle, and in three or four days deposits small transparent crystals, often crossing each other in such a manner as to resemble the spokes of a wheel. They are four-sided prisms, terminated by very long four-sided pyramids. Vauquelin considered them as crystals of phosphate of lime; but that salt never crystallizes in four-sided prisms. It is much more probable that the crystals are of ammonia-phosphate of magnesia, which assumes the shape of a rectangular prism with a square base.

If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface thickens, and a number of white round bodies appear on different parts of it. These, according to Vauquelin, are concretions of phosphate of lime. They amount, he says, to three per cent. of the weight of the semen. If at this period of the evaporation the air become moist, crystals of carbonate of soda, and doubtless of common salt, appear in the substance. The evaporation does not go on to complete desiccation unless the air be very dry and the temperature at least as high as 77°, the residue amounts to one-tenth of the semen. It is translucent like horn, and brittle.

When semen is kept in very moist air, at the temperature of about 77°, it acquires a yellow colour like that of the yolk of an egg; its taste becomes acid, it exhales the odour of putrid fish, and its surface is covered with abundance of the *Byssus septica*.

When dried semen is exposed to heat in a crucible, it melts, acquires a brown colour, and exhales a yellow fume having the odour of burnt horn. When the heat is raised the matter swells,

* Vauquelin, Ann. de Chim. ix. 71.

becomes black, and gives out a strong odour of ammonia. If the residue be lixiviated with water, an alkaline solution is obtained, which gives crystals of carbonate of soda, and doubtless of common salt. A little phosphate of lime remains.

The constituents of semen, according to the analysis of Vauquelin, are,

Water,	90
Spermatin,	6
Phosphate of lime,	3
Soda,	1
	100

But this analysis was made before chemistry had acquired the requisite precision. It cannot, therefore, be depended on. In a previous chapter of this volume, while treating of *spermatin*, the more recent experiments of Berzelius on human semen have been stated.

II. Fourcroy and Vauquelin published a set of experiments on the milt of the carp in the year 1807,* from which it appears that the nature and composition of this substance is different from that of every other hitherto examined. The milt of this fish, as is well known, has a whitish colour, a soft consistence, a greasy feel, and a smell similar to that of fish. It is neither acid nor alkaline. When triturated with potash, no ammoniacal odour is exhaled, and it forms with the alkali a thick magma. Thirty parts of milt mixed with six parts of potash, and a sufficient quantity of water, and distilled, yielded only traces of ammonia, coming obviously from some muriate of ammonia, which exists naturally in the milt. When milt is dried slowly in a moderate heat, it loses three-fourths of its weight, becomes yellow and brittle. When heated in a platinum crucible it softens and then melts, exhaling yellow vapours having the smell of animal oil. The charcoal formed contains a notable quantity of uncombined phosphoric acid, together with some phosphate of lime and phosphate of magnesia. As the acid did not exist in the milt, it must have been formed during the combustion; and hence it follows, that milt contains a notable quantity of phosphorus as a constituent.

One hundred and twenty-three parts of fresh milt, cautiously

* Ann. de Chim. lxiv. 5.

distilled in an earthen-ware retort, gradually heated to whiteness, furnished the following products: 1. A great deal of colourless water holding in solution carbonate of ammonia, a good deal of prussiate of ammonia, and traces of muriate of ammonia; 2. A transparent oil slightly yellow; 3. A fluid blood-red oil; 4. A thick blackish-brown oil; 5. Crystals of carbonate and prussiate of ammonia; 6. A quantity of phosphorus; 7. A small quantity of carbonic acid and heavy inflammable air. The charcoal remaining in the retort amounts to 7½ parts, and contains no disengaged phosphoric acid.

When milt is triturated in distilled water, a white opaque liquid is obtained, which does not become transparent though passed through the filter. When the liquid is boiled, an albuminous matter coagulates; and if the residuary liquid be evaporated sufficiently, it gelatinizes; a proof that it contains gelatin. Alcohol digested on milt dissolves a substance which possesses the properties of animal soap. When it is separated, the milt becomes dry and harsh to the feel; a proof that its unctuosity was owing to the presence of the animal soap.

Thus it appears that milt contains albumen, gelatin, phosphorus, phosphate of lime, phosphate of magnesia, and muriate of ammonia.

CHAPTER XIV.

OF SYNOVIA.

Within the capsular ligament of the different joints there is contained a peculiar liquor, intended evidently to lubricate the parts and to facilitate their motion. This liquid is known among anatomists by the name of *synovia*.*

The chemical constitution of this liquid has been but imperfectly ascertained. It is mucilaginous like the white of egg,

* The word *synovia* (from συν and ωον, probably from its resemblance to the white of an egg), is said to have been first used by Paracelsus, and to have signified the juice which nourishes the different parts of the body. I find the word *synophia* used by him in that sense. See his *Scholia in libros paragraphorum; de Gutta. Opera Paracelsi*, i. 547. Geneva edition.

transparent and yellowish or reddish. Its taste is slightly saline, and its smell similar to that of serum of blood.

1. M. Dupuytren had an opportunity of examining the synovia of the knee of a man who was affected with a disease of that joint. It was viscid, thready, transparent, and slightly reddish. Its specific gravity was 1·05.* MM. Lassaigne and Boisset obtained from Dr Amussat a small quantity of synovia from the large joints of several dead bodies, which enabled them to make some chemical experiments on it.† From the method of extracting it by a sponge, it was necessarily mixed with distilled water. It was colourless, had a slight smell, frothed when agitated, and restored the colour of reddened litmus-paper. Nitric acid and alcohol threw down white flocks, and the infusion of nut-galls occasioned a yellowish-white precipitate. These reagents show the presence of albumen in human synovia.

When evaporated by a gentle heat, a white pellicle formed on its surface, which increased in thickness, and at last was precipitated in flocks, which were separated by the filter. The liquid being evaporated, gave a yellow extract, having a saline and sharp taste. And cubic crystals gradually formed in it. Alcohol dissolved a yellow animal matter. The residue of the alcoholic solution being calcined, yielded chloride of sodium, mixed with a little chloride of potassium. The portion insoluble in alcohol dissolved in water, and contained carbonate of soda, and an animal matter containing azote, the nature of which was not ascertained. They could detect no uric acid in human synovia. The albumen precipitated contained a little fatty matter.

According to this analysis, human synovia contains,

Albumen.
Fatty matter.
An animal substance soluble in water.
Soda.
Chloride of sodium and potassium.
Phosphate and carbonate of lime.

Dr Bostock made some experiments on the synovia from the knee of a man. It contained albumen coagulated and half-coagulated, and a mucoso-extractive matter always found in albuminous fluid.‡

* Jour. de Medecine, Chirurgie, &c. ii. 466.
† Jour. de Pharmacie, viii. 206. ‡ Annals of Philosophy, xii. 121.

2. M. Margueron examined the synovia of the ox in 1792.* The synovia which he subjected to experiment was from the joints of the legs, probably the knee-joint; though that is not stated.

This synovia, when it had just flowed from the joint, was a viscid semitransparent fluid, of a greenish-white colour, and a smell not unlike that of frog's spawn. It soon acquired the consistence of jelly, and this happened whether it was kept cold or hot, and whether the air had access to it or was excluded. This consistence did not continue long. The synovia soon recovered its fluidity, while at the same time a thready-like matter was deposited.

It readily mixed with water, and imported to that liquid a portion of its viscidity. When the mixture was boiled it became milky, and deposited some pellicles, but the viscidity was not diminished.

Alcohol precipitates albumen from synovia. Margueron found the amount of albumen in the synovia which he examined to be 4·52 per cent. The liquid still continued viscid. But when acetic acid was added to it, the viscidity disappeared, the liquid became transparent, and deposited white threads possessing the following properties: 1. It had the colour, smell, taste, and elasticity of gluten of wheat. 2. It was soluble in concentrated acids, and alkaline hydrates. 3. It was soluble in cold water; the solution frothed. Alcohol and acids threw it down in flocks. It amounted to 11·86 per cent., doubtless weighed while moist.

The liquid, after the separation of this substance, being concentrated, deposited crystals of acetate of soda, showing the existence of soda in synovia. The quantity of soda amounted to 0·71 per cent.

When strong sulphuric, muriatic, nitric, acetic, or sulphurous acid was poured into synovia, white flocks precipitated, but they were soon redissolved, and the viscidity of the liquid continued. When very much diluted these acids precipitate the thready matter, and the viscidity of the synovia disappears.

Synovia, when kept in a dry atmosphere, gradually evaporated, leaving a scaly residue, in which cubic crystals and a white saline efflorescence were apparent. The cubic crystals of common salt amounted to 1·75 per cent. of the synovia. The white efflorescence was carbonate of soda.

* Ann. de Chim. xiv. 124.

Synovia soon putrefied in a moist atmosphere, and during the putrefaction ammonia was exhaled. When distilled *per se*, water, ammonia, empyreumatic oil, and carbonate of ammonia came over. The residue contained common salt, carbonate of soda, and phosphate of lime.

According to Margueron, the synovia of the ox is composed of,

Fibrous matter,	11·86
Albumen,	4·52
Common salt,	1·75
Soda,	0·71
Phosphate of lime,	0·70
Water,	80·46
	100·00

It is impossible not to be struck by the great resemblance of the synovia examined by Margueron to the serum of blood. Is it not possible that he may have obtained serum or lymph instead of synovia?

3. Dr John made some experiments on the synovia extracted from the healthy joint of a horse.* It was light yellowish-red, clear, of the specific gravity of 1·099, restored the blue colour to reddened litmus-paper, and was coagulated by a boiling heat. He found the constituents as follows:

Water,	92·8
Albumen,	6·4
Animal matter not coagulable, with carbonate of soda and common salt,	0·6
Phosphate of lime,	0·15
Phosphate of soda, Ammoniacal salt,	trace.
	99·95

He examined also the synovia from an ankylosed joint in consequence of a wound. It was red, muddy from flocks of albumen, thick and reddened litmus-paper. It coagulated when heated. It contained insoluble albumen, soluble albumen, free phosphoric acid, and the same salts as healthy synovia.

4. In 1817, M. Vauquelin examined the synovia of an elephant that died in the Jardin du Roi at Paris.†

* Chem. Schr. vi. 146. † Jour. de Pharmacie, iii. 289.

It had a slight colour, doubtless, from an admixture of a little blood. Its consistence is thready, like that of a decoction of lintseed, feel soft, taste slight, but saline. On standing a few hours it deposits white filaments, apparently of fibrin, (6 ounces deposited only 1 grain.) But it amounted to only $\frac{1}{3456}$th of the synovia. He found its constituents similar to those of the synovia of the ox. Vauquelin conceives, that, besides albumen, it contains a peculiar substance, neither coagulable by heat nor acids, but capable of being precipitated by tannin. He found also soda, chloride of sodium, and chloride of potassium, but could not discover any alkaline phosphates,

5. Mr Brande, in the year 1809, made some experiments on the synovia of the shark (*Squalus maximus.*)* In these fish there exist in the vertebræ a peculiar synovia, which fills the cavities between each. Mr Brande found this synovia of the specific gravity 1·027. It had the smell of fish oil. It did not mix with water till the action was assisted by heat. The solution was neither precipitated by boiling, nor by alcohol, nor by tannin. It contains in solution a substance approaching to mucus by its properties; but which, in certain circumstances, is transformed into a modification of gelatin and albumen. It is probably a substance *sui generis.*

Such is the imperfect collection of chemical facts hitherto ascertained respecting synovia. We do not know as yet whether it contains any peculiar animal principle, though such an opinion is at least probable.

CHAPTER XV.

OF MUCUS.

THE word *mucus* in the Latin language signifies properly the gelatinous-looking matter secreted in the nose, to defend it from the action of the air that passes through it, and vulgarly called *snot.* But in chemistry, it is used to denote the slimy transparent matter, which lines all the cavities of the body through which foreign matters pass, in order to protect the internal surface of

* Phil. Trans. 1809, p. 184.

these cavities from the action of those foreign matters. It is distinguished by the name of the cavity in which it is secreted. Thus we have the *mucus of the mouth, of the nose, of the trachea; of the stomach and intestines, of the gall-bladder, and of the urinary organs.*

By mucus is meant in chemistry a solid body, which does not dissolve in water; but which absorbs that liquid, swells up, becomes soft, viscid, and even half-fluid in some cases. It is secreted by small glands scattered over the mucous membranes, which throw it out, and spread it equably over the whole surface of the mucous membrane. It is soaked with water, holding in solution the same salts which exist in the serum of the blood.

Its characters vary somewhat in different mucous membranes, doubtless according to the nature of the foreign substances from which it is intended to protect the membrane on which it is spread. On this account it will be requisite to give the chemical properties of the different species of mucus so far as they have been determined.

1. *Mucus of the mouth.*—This mucus subsides from saliva left at rest in small white flocks. In sulphuric, muriatic, and acetic acids, it becomes transparent and horny. But it does not dissolve in these acids, nor give out any phosphate of lime to them; though when incinerated it always leaves traces of that salt.*

2. *Mucus of the nose.*—This mucus, when secreted from a healthy membrane, is white or colourless, translucent, loaded with water, so as to assume much of the appearance of that portion of gum-tragacanth which is insoluble in cold water after it has imbibed as much as it can of that liquid. In the first stage of a catarrh, it is secreted in greater abundance than usual, and is at first transparent and almost altogether liquid; but as the disease advances the mucus acquires more and more consistency, becomes white and opaque, and finally yellow and nearly solid. Healthy mucus of the nose, according to the analysis of Berzelius, is composed of the following constituents:

* Berzelius.

Water,	933.7
Mucus,	53·3
Chlorides of potassium and sodium,	5·6
Lactate of soda with animal matter,	3·0
Soda,	0·9
Albumen and animal matter soluble in water, but insoluble in alcohol, with trace of phosphate of soda,	3·5
	1000·0*

When the mucus of the nose is immersed in water, it imbibes so much as to become transparent and almost invisible; and when dried on blotting-paper, loses nearly all the moisture which it had imbibed. This may be repeated as often as we please; but the mucus gradually assumes a yellow colour. Though boiled in water it does not lose its mucilaginous nature.

It dissolves in dilute sulphuric acid. Nitric acid at first coagulates it; but if the digestion be continued the mucus is at last dissolved into a clear yellow liquid. Acetic acid hardens, and does not dissolve it even at a boiling heat. Caustic alkali renders it at first more viscid; but at last dissolves it into a clear liquid. Tannin coagulates it.

3. Mucus of the bronchiæ in a state of health, when expectorated, is pretty similar to the mucus of the nose, only its consistence is greater and its colour bluish. It possesses, so far as I have tried them, the same characters as the mucus of the nose. The blue colouring matter is probably derived from matter suspended in the air drawn into the lungs. It has been remarked to be darker in those who live in great towns than in those who live in the country.

Dr Pearson made numerous experiments on the matter expectorated from the lungs, which were published in the Philosophical Transactions for 1809. He distinguished seven different kinds of it. 1. The jelly-like transparent kind of a bluish hue expectorated in health. This is the true mucus of the bronchiæ. 2. The thin mucilage-like transparent matter so copiously expectorated in bronchial catarrh. 3. The thick opaque straw-coloured, or white and very tenacious matter coughed up in a great variety of bronchial and pulmonary affections. 4. Puriform matter secreted without any breach of surface of the

* Annals of Philosophy, ii. 382.

bronchial membranes in pulmonary consumption. 5. Mixtures of the second, third, and fourth kinds of matter. 6. Pus from vomicæ of tubercles. 7. Pus from vomicæ of simple inflammation of the lungs without tubercles.

He made no attempt to ascertain the properties of the mucus contained in these expectorated matters, but determined the saline contents, and found them to be, 1. Common salt, in the proportion of from 0·15 to 0·25 per cent.; 2. Phosphate of lime, about 0·05 per cent.; 3. Ammonia united probably with phosphoric acid; 4. Phosphate of magnesia? 5. A sulphate; 6. Carbonate of lime; 7. Silica? 8. Oxide of iron.

Dr Golding Bird has made some interesting experiments on the mucus secreted so abundantly during the first stage of acute bronchitis. When freed from air bubbles it is a transparent colourless liquid, rendered reddish brown by sulphuric acid, but the colour disappears on adding water. Nitric acid at first coagulates it, but dissolves it when heated. Muriatic acid gives it a lilac tint. Ammonia, by the assistance of heat, produces a gelatinous solution, becoming turbid when diluted with water. Acetic acid produces a partial coagulation. Infusion of nutgalls causes a copious precipitate. When evaporated to dryness it leaves a gum-like residue, leaving, when incinerated, a white alkaline carbonate.

When exposed for a few days to the air it lets fall a cream-coloured deposit, possessing the characters of coagulated albumen.*

Dr Babington has shown that the bronchial mucus is always alkaline.†

4. *Mucus of stomach and intestines.*—In these organs the mucus covers the whole internal surface. When an animal is killed after a long fast we may scrape a great deal of mucus from the mucous membrane, and obtain it pure by washing it in distilled water. It is a white translucent gelatinous-looking substance, without taste or smell. When dried it loses the property of becoming mucilaginous when water is poured over it; but if we add a little alkali to the water the gelatinous state is instantly restored. From this we see the use of the small quantity of soda which this mucus always contains in its natural state.

Acids coagulate it, even acetic acid, and often make it assume the form of a kind of cake. Acids do not dissolve it even at a

* Phil. Mag., (3d series) xiii. 15. † Guy's Hospital Reports, ii. 539.

boiling temperature; though they dissolve something. If we decant off the acid, and then treat the mucus with water, an additional portion is dissolved, these solutions are precipitated by the infusion of nut-galls, but very seldom by prussiate of potash. Very dilute caustic potash or soda readily dissolves the mucus of the intestines. From this solution it is thrown down in great part by the acids. It is dissolved also by very dilute ammonia, and equally precipitated by acids.

5. *Mucus of gall-bladder.*—This mucus in its natural state is more transparent than that of the nose, but has a yellow colour obviously from a mixture of bile. When dried it loses the property of becoming gelatinous from imbibing water, all the acids coagulate it into a yellow mass, which reddens litmus. Alkalies make it again viscid. Alcohol coagulates it into a horny mass, which cannot again be rendered gelatinous. If we neutralize by an acid the solution of this mucus in potash ley, we obtain a muddy thready solution.

According to Fromherz and Gugert, the solution of the mucus of the human gall-bladder in potash ley is not precipitated by muriatic acid, unless we add at the same time a portion of tincture of nut-galls.*

Tiedemann and Gmelin made several experiments upon the mucus from the gall-bladder of oxen. It was soft and greenish in its natural state, but when dried, it became hard, brittle, and deep grayish-green. It swelled when heated, and burnt with flame, and giving out the smell of burning horn. The ashes constituted 8 per cent. of the dried mucus. They consisted chiefly of phosphate of lime with a little carbonate, and contained traces of an alkaline sulphate and chloride. This mucus was partially dissolved by dilute sulphuric and muriatic acid, and the solution was slightly precipitated by tincture of nut-galls, but nitric acid did not seem to dissolve any of it. What remained insoluble in the acids being digested in hot water, was partially dissolved and the solution was precipitated by tincture of nut-galls. It softened and partly dissolved in ammonia.†

6. *Mucus of urinary bladder and urethra.*—When fresh, it is white and translucent. When dried, it assumes a rose-red colour, and is but little softened by water. It is not altered by acids; ammonia sometimes increases its viscosity, sometimes not.

* Schweigger's Jour. l. 70. † Recherches sur la Digestion, i. 43.

When heated over a spirit lamp it dries, swells a little, and is charred, and burning with a small flame. When digested in ether, a little fatty matter is dissolved, to which the flame was doubtless owing. When examined by the microscope, it appears composed of irregular transparent plates, mostly colourless, though sometimes yellowish. When globules appear in it the mucus is probably partially converted into pus. The diameter of these globules varies from $\frac{1}{1200}$th to $\frac{1}{1800}$th of an inch.

CHAPTER XVI.

OF TEARS.

The fluid which is employed in lubricating the eye, and which is emitted in considerable quantity, when we express grief by weeping, is known by the name of *tears*. It is secreted by the lachrymal gland, a conglomerate gland about three-quarters of an inch in length, and half an inch in breadth, situated in the upper and outer part of the orbit. No attempt has been made to make a chemical examination of the tears, since the experiments of Fourcroy and Vauquelin in 1791.*

The liquid, called *tears*, is transparent and colourless like water. It has no perceptible smell, but its taste is sensibly saline. Its specific gravity has not been determined, though it is known to be heavier than distilled water. It tinges syrup of violets green, and of course contains a free alkali. It may be mixed with water in all proportions. Alkalies unite with it readily, and render it more fluid. The mineral acids do not sensibly alter it. When exposed to the air, it gradually evaporates and becomes thicker. About the end of the evaporation a number of cubic crystals of common salt make their appearance. They give a green tinge to vegetable blues, and therefore contain an excess of alkali. The mucous animal matter of tears acquires a yellow colour as it dries. Tears boil like water, excepting that a considerable froth collects on the surface. When boiled to dryness over the steam-bath, tears lose 96 per cent. of their weight, which flies off in the state of water. The remaining 4 parts have a yellowish colour. When strongly heated,

* Jour. de Phys. xxxix. 254.

water and a little empyreumatic oil is driven off. The residue consists of common salt mixed with some soda and small quantities of the phosphates.

Alcohol precipitates white flocks from tears. These flocks were considered by Fourcroy and Vauquelin as constituting a species of mucus. This mucus, they say, has the property of absorbing oxygen from the atmosphere, and of becoming thick and viscid, and of a yellow colour. It is then insoluble in water, and remains long suspended in it without alteration. When chlorine is added to tears, a yellow flocky precipitate falls, possessing the same properties as inspissated mucus. This property of the mucus of tears enables us to understand the alterations which that liquid undergoes when long exposed to the action of the atmosphere, as is the case with those persons who labour under a *fistula lachrymalis.*

The substances found in tears by Fourcroy and Vauquelin are the following:

Water.	Soda.
Mucus.	Phosphate of lime.
Common salt.	Phosphate of soda.

CHAPTER XVII.

OF THE LIQUORS OF THE EYE.

THE globe of the eye consists of several coats inclosing within them three different humours. The one farthest back, and constituting a considerable portion of the eye-ball, is called the *vitreous humour.* It is a transparent and colourless liquid inclosed in a great number of cells. Between the cornea and the lens of the eye, there is another colourless and transparent liquid called the *aqueous humour;* and the crystalline lens, though not liquid but solid, has got the improper name of the *crystalline humour* of the eyes.

The first attempt to examine these three humours, and to determine their chemical constitution, was made by Mr Chenevix in 1802.* He made his experiments on the eyes of sheep and oxen, and made some observations also on the humours of the human

* Phil. Trans. 1803, p. 195.

eye. Soon after, Mr. Nicolas made a set of experiments on the eyes of sheep and oxen, and announced the presence of phosphate of lime in all the humours, though Chenevix had not been able to detect any.* In 1808, Berzelius published the second volume of his Animal Chemistry, in which he gave an account of a set of experiments which he had made to determine the chemical constitution of these humours.† The same experiments were republished in the General Views of the Composition of Animal Substances, published in English in 1813.‡ He was equally unsuccessful with Chenevix in his attempts to detect the presence of phosphate of lime in these humours.

I. *Eye of the sheep.*

1. The aqueous humour of the eye of the sheep is a clear and transparent liquid like water, having (while fresh) very little taste or smell. Its specific gravity at 60° is 1·0090, as determined by Chenevix. Nicolas rates it as low as 1·C009.

It scarcely alters vegetable blues while fresh, but when kept, ammonia is generated, which gives it an alkaline reaction. When heated to the boiling temperature, a very slight coagulum appears. Chenevix says that when evaporated to dryness, it leaves a residuum weighing not more than eight per cent. of the original liquid. But there must be a mistake in the statement, as no other experimenter has obtained a residue weighing so much as 2 per cent. Tincture of nut-galls occasions a precipitate both before and after it has been boiled. From this Chenevix infers that the aqueous humour contains *gelatin.* But it is more probable that the precipitate by tannin after boiling proceeds from a residue of albumen which had not been thrown down by boiling. Nitrate of silver detects in this liquor the presence of chlorine. Acetate of lead throws down a white matter, but no precipitate is produced by any other metallic salt.

The constituents of the aqueous humour of the sheep's eye, according to Berzelius, are

Water,	98·10
Albumen,	trace.
Chlorides and lactates,	1·15
Soda with animal matter soluble only in water,	0·75
	100·

* Ann. de Chim. liii. 307.

† Djurkemie, ii. 206.

‡ Annals of Philosophy, ii. 385.

2. The vitreous humour possesses the same properties as the aqueous. Its specific gravity, as determined by Chenevix, is the same as that of the aqueous humour. Its constituents, according to the analysis of Berzelius, are

Water, ...	98·40
Albumen, ...	0·16
Chlorides and lactates, . .	1·42
Soda, with animal matter soluble only in water,	0·02
	100·00

3. The crystalline lens is solid and transparent, it is composed of a congeries of very fine coats. Its specific gravity is 1·1000. But it is densest and most solid in the centre, and the specific gravity and consistency gradually diminish as we approach the circumference. Chenevix found the weight of a fresh crystalline lens of an ox to be 30 grains, and its specific gravity was 1·0765. On paring away the external portion, and leaving only a central nucleus weighing 6 grains, the specific gravity of this nucleus was 1·1940.

It dissolves almost entirely in water. The solution is partly coagulated by heat and gives a copious precipitate with tannin, both before this coagulation and after it. Berzelius conceives that this property is owing to the presence of a peculiar matter possessing all the characters of the colouring matter of the blood, except the red colour. But what was considered as the colouring matter of blood when Berzelius made his experiments, was chiefly albumen, but containing a very little fibrin and hematosin. Hence it is probable that this peculiar matter is chiefly albumen. The constituents of the lens were found by him to be,

Water, ...	58·
Peculiar matter, ...	35·9
Chlorides, lactates, animal matter soluble in alcohol,	2·4
Animal matter soluble only in water, with phosphates,	1·3
Insoluble cellular membrane, . .	2·4
	100·0

The peculiar matter of the lens when burnt leaves a little ash containing a very small portion of iron. When its solution in water is coagulated by boiling, the liquid in which the coagulum was formed reddens litmus, has the smell of the humours of the muscles, and like them, contains free lactic acid.

II. The humours of the human eye are composed of the same ingredients as those of the sheep; though they differ somewhat in their specific gravity. The specific gravity of the aqueous and vitreous humours is 1·0053, and that of the crystalline lens 1·0790 as determined by Chenevix.

III. The humours of the eyes of oxen resemble those of the sheep in their composition. The specific gravity of the aqueous and vitreous humours is 1·0088, and that of the lens 1·0765, as determined by Chenevix.

From the specific gravities of the aqueous and vitreous humours compared with that of the lens in different animals, Chenevix has concluded that the difference between the density of the aqueous and vitreous humours and of the lens, is in the inverse ratio of the diameter of the eye, taken from the cornea to the optic nerve.

IV. Chenevix examined also the humours of the eyes of birds. He found them composed of the same materials as the eyes of sheep. But in birds the specific gravity of the vitreous humour was greater than that of the crystalline.*

V. Lassaigne examined the vitreous humour of a blind horse. Its specific gravity was 1·059, while that of the vitreous humour from a healthy eye was only 1·0008. The vitreous humour in the blind horse was very thick, yellowish, red and muddy, from coagulated albumen floating in it. The albumen in solution amounted to about eight per cent. It was yellow, soluble in alcohol, and resembled the brown colouring matter of bile, and the salts (similar to those in blood) were more abundant than in the healthy vitreous humour.†

In the year 1821, Dr Rudolph Brandes made a chemical analysis of the crystalline lens of a horse,‡ and obtained the following constituents:

Water,	75
Albumen soluble in cold water,	7
Albumen insoluble in cold water and approaching fibrin in its nature	12
Sulphate, muriate, lactate of potash and soda, with a substance precipitated by tincture of nut-galls,	1
	95

* Journal of the Royal Institution, i. 297.
† Jour. Chim. Med. iv. 476.
‡ Schweigger's Jour. xxxi. 194.

Brought over,		95
Phosphate of lime,		trace.
		95
	Loss,	5
		100

VI. A curious set of experiments has been made by Leopold Gmelin on the black pigment, which lines the choroid coat of the eye. From 500 eyes of oxen and calves he collected 75 grains of this substance. Its colour is blackish brown. It is tasteless, and adheres to the tongue like clay. It is insoluble in water, alcohol, ether, oils, lime-water, and distilled vinegar. It dissolves in potash and ammonia when assisted by heat, and is again precipitated by acids. Sulphuric acid dissolves it and acquires a black colour. Muriatic acid forms only an imperfect solution. Nitric acid dissolves it, and changes its colour to reddish-brown. When distilled it yields water, a brown oil, and carbonate of ammonia. It gives out at the same time carburetted hydrogen, carbonic oxide, azotic and oxygen gas. The coal remaining in the retort consists almost entirely of charcoal. *

CHAPTER XVIII.

OF CERUMEN.

CERUMEN* or *ear-wax* is a yellow-coloured liquid, secreted by the glands of the auditory canal, which gradually becomes concrete by exposure to the air. It is intended to lubricate the canal, to keep the parts soft, and to prevent insects from making their way to the tympanum. This secretion was first subjected to a chemical examination by Fourcroy and Vauquelin, who was supplied with a sufficient quantity of serum for the purpose by M. Hallé. Fourcroy has stated the result of this examination in his *Systeme des Connoissances Chimiques*.‡ In the second volume of Berzelius's *Animal Chemistry*, published in 1808, he

* Schweigger's Jour. x. 507.

† From κηρος, *wax*, from its resemblance to wax.

‡ Vol. ix. p. 454 of the English translation.

merely gives the result of Vauquelin's analysis, without adding any additional facts of his own.* Nor does he take any notice of cerumen in his *General Views of the Composition of Animal Fluids*, published in 1813.† But in the seventh volume of his Traité de Chimie, published in 1833, he gives the result of a set of experiments which he had made on that secretion. To these chemists, so far as my knowledge extends, we are indebted for all the chemical knowledge of cerumen which we at present possess.

When collected, it has an orange-yellow colour, and a bitter taste, and has a consistency nearly equal to that of soft wax. When slightly heated on paper it melts and stains the paper like a fixed oil; at the same time it emits a slightly aromatic odour. On burning coals it softens, gives out a white smoke similar to that emitted by burning fat. It afterwards melts, swells, becomes dark-coloured, and emits an ammoniacal and empyreumatic odour. A light coal remains behind. When cerumen is agitated in water, it forms a kind of emulsion, which soon putrefies, depositing at the same time white flocks.

According to Vauquelin it is composed of,

Brown oil,	.	62·5
Albumen,	.	37·5
		100·0

The oil is butyracious and soluble in alcohol. The albumen contains a bitter extractive matter, the proportion of which was not ascertained.

Berzelius found that when cerumen was treated with ether it swelled up a little, and the ether extracted a fatty matter, which scarcely communicated any colour to it. When we mix the ether with water and distil, the fatty matter remains on the surface of the water without being in the least soluble in that liquid. This fatty matter has the consistence of duck's grease. It does not redden litmus, melts easily into a transparent yellowish oil; but resumes its white colour on cooling and concreting. This fatty matter contains stearin and olein separable from each other by alcohol. It is easily converted into a soap, which has a smell analogous to sweat. When the soap is decomposed by muriatic acid, the oily acids separate in a white powder, which melts at about 104°.

* Djurkemien, ii. 228. † Annals of Philosophy, ii. 19.

The cerumen thus deprived of its fat by ether gives a brownish yellow colour to alcohol. When the alcohol is evaporated it leaves a brownish-yellow extractive matter, which is soluble in water. When the aqueous solution is evaporated to dryness, it leaves the matter under the form of a deep-yellow, transparent, brilliant varnish. It has no smell, but an extremely bitter taste. When exposed to the air it softens and becomes viscid like turpentine. When burnt it gives out an animal odour, and leaves an ash composed of carbonate of potash and carbonate of lime. Its solution in water is yellow, and is not precipitated by nitrate of silver, showing that it contains no chloride. Oxalate of ammonia throws down lime. Nitrate of lead precipitates the bitter tasted substance, and discolours the liquid. It is also precipitated completely by the protochloride of tin; but not by corrosive sublimate, and very imperfectly by the tincture of nut-galls. It is obviously a peculiar animal principle, which ought to be distinguished by a peculiar name. The term *otin* might perhaps answer the purpose.

When the portion of cerumen insoluble in ether and alcohol is digested in water, that liquid dissolves a small quantity of a pale-yellow matter, which may be obtained by evaporating the water. It has a sharp taste, and is neither precipitated by lime-water nor by diacetate of lead, corrosive sublimate, nor infusion of nut-galls.

The residue of the cerumen insoluble in ether, alcohol, and water constitutes a great proportion of it. When this residue is digested in acetic acid, it swells up and becomes gelatinous; but when we dilute the mixture with water, the acid, even after several weeks' digestion, dissolves but a portion of the whole. The solution is yellowish, and when evaporated to dryness, leaves a mass insoluble in water, but soluble in dilute acetic acid, from which it is precipitated by prussiate of potash, showing that it contains albumen. The prussiate of potash does not precipitate the whole. For the liquid is still precipitable by the infusion of nut-galls.

The portion of cerumen insoluble in acetic acid is much more considerable than that which dissolves. It is a brownish, mucilaginous, translucent mass, which falls rapidly to the bottom of the liquid. When digested in caustic potash at the temperature of about 100°, very little of it dissolves. The solution is yellow-

ish. It is not precipitated when supersaturated with acetic acid, and prussiate of potash does not throw down any thing from the acid liquor, but the infusion of nut-galls throws down a copious precipitate.

The portion insoluble in potash when burnt exhales the smell of burning animal matter, and leaves a very little alkaline ash. Boiled in a very concentrated solution of caustic potash, it gives the liquor a brownish-yellow colour, and emits the smell of horn subjected to the same treatment. A little matter falls, which is a compound of the dissolved substance and potash. It is soluble in water. Thus, the substance in cerumen, which resists the action of all the reagents except very concentrated caustic potash, possessed many of the properties of horn, though it differs from that substance in several of its characters.

From these experiments of Berzelius, it appears, that cerumen is composed of,

Stearin.	Yellow matter soluble in water.
Elain.	Albumen (uncoagulated).
Otin.	Albumen (coagulated).
	Lactates of lime and potash or soda.

CHAPTER XIX.

OF PERSPIRATION AND SWEAT.

THAT a quantity of matter is constantly emitted from the skin has been long known, as this matter in most cases is dissipated as fast as it is thrown out of the body, and of course without being perceived, unless peculiar contrivances be used to detect it; it has got the name of *insensible perspiration.*

Many experiments have been made to determine the quantity of matter perspired through the skin. For the first set and not the least remarkable, we are indebted to Sanctorius, who continued them for no less than thirty years. According to him, the average quantity of matter perspired through the skin in a natural day amounts to not less than 50 ounces.* A similar set of experiments was afterwards made in France by Dodart, and in England by Keil. According to Dodart the perspira-

* See Quincy's *Medicina statica*, p. 54.

tion amounts to 24 ounces in twenty-four hours. According to Keil it is rather more than 31 ounces, or very nearly 2 lbs avoirdupois.* Dr Bryan Robertson and Mr Rye made a similar set of experiments in Ireland, as did Dr Lining in Carolina. But these experimenters neglected to distinguish the matter perspired through the skin from what was thrown out by the lungs.

Lavoisier and Seguin were the first persons who attempted to ascertain the amount of the matter perspired by the skin, and to separate it from what was thrown out by the lungs. A bag composed of varnished silk, and air-tight, was procured, within which Seguin, who was usually the subject of experiment, was enclosed; every part of the body being included. There was a slit in the bag opposite to the mouth, and the edges of the slit were accurately cemented round the mouth by means of a mixture of turpentine and pitch. Thus everything emitted from the body was retained in the bag, except what made its escape from the lungs during expiration. By weighing himself in a sensible balance before the experiment began, and again after he had been for some time enclosed in the bag, the difference of weight gave the matter exhaled from the lungs. While the weight of the bag before and after the experiment gave data for determining the quantity of matter exhaled from the skin during the same length of time. The following facts were ascertained by these experiments:

1. The maximum of matter perspired in a minute amounted to 26·25 grains troy; the minimum to 9 grains; which gave 17·63 grains at a medium in the minute, or 52·89 ounces in twenty-four hours. This is very near the quantity stated by Sanctorius as the result of his numerous experiments.

2. The quantity perspired is increased by drink; but not by solid food.

3. Perspiration is at its minimum immediately after a repast. It reaches its maximum during digestion.†

Mr William Cruikshanks published a work on insensible perspiration in 1795. He seems to have been the first person who thought of collecting the matter perspired so as to be able to judge of its nature. He inclosed his hand within a glass vessel and luted its mouth to his wrist by means of a bladder. The interior surface of the glass became gradually dim, and drops of

* See Quincy's *Medicina statica*, p. 323.

† Fourcroy, i. 276, *English translation*.

water trickled down. By keeping his hand thus enclosed for an hour, he collected 30 grains of a liquid which possessed the properties of water. On repeating the same experiment at nine in the evening (thermometer 62°), he collected only 12 grains. The mean of these two trials is 21 grains.* But as the hand is more exposed than the trunk of the body, it is reasonable to believe that the perspiration from the trunk is greater than from the hand. Let us therefore take 30 grains per hour as the mean, and let us suppose with Cruikshanks, that the hand is one-sixtieth of the surface of the body. The total perspiration in twenty-four hours would amount to 43,200 grains, or 90 ounces troy. This being much more than the quantity stated by Lavoisier and Seguin, or even than the amount ascertained by Sanctorius, we must conclude that more matter is perspired from the hand than the trunk, provided Cruikshanks' estimate of the ratio between the surface of the hand and the body be not erroneous.

He repeated the experiment again after hard exercise, and collected in an hour 48 grains of water. He found that this aqueous vapour pervaded his stocking with ease, and that it made its way through a shamoy leather glove, and even through a leather boot, though in much smaller quantity than when the leg wanted that covering.†

It is evident from these experiments of Cruikshanks just stated, that the matter perspired consists chiefly of water. But it follows also, from his experiments, that carbonic acid gas is evolved from the skin. The air of a glass vessel in which his hand and foot had been confined for an hour contained carbonic acid gas; for a candle burnt dimly in it, and it rendered lime-water turbid.‡ M. Jurine found that air which had remained for some time in contact with the skin consisted in a great measure of carbonic acid gas.§ The same conclusion follows from the experiments of Ingenhousz and Milly.‖ Trousset observed that gas was separated copiously from the skin of a patient of his while bathing.¶

Besides water and carbonic acid, the skin emits also an odorous substance. That every animal has a peculiar smell is well known. The dog can discover his master, and even trace

* On Insensible Perspiration, p. 68.
† Ibid. p. 82.
‡ On Insensible Perspiration pp. 70 and 81.
§ Encyc. Meth. Med. i. 515.
‖ Encyc. Meth. Med. p. 511.
¶ Ann. de Chim. xlv. 73.

him to a distance by the scent. A dog chained for some hours after his master had set out on a journey of some hundred miles, followed his footsteps by the smell, and found him on the third day in the midst of a crowd.* Mr Cruikshanks, to discover the nature of this substance, wore for a month the same vest of fleecy hosiery during the hottest part of the summer. He found an oily-looking substance accumulated in considerable masses on the nap of the inner surface of the vest, in the form of black tears. When rubbed on paper it rendered it transparent, and gave it a greasy stain. It burnt with flame, leaving a charcoal behind it.†

Thenard repeated this experiment of Cruikshanks in 1806.‡ A flannel jacket, previously well washed in distilled water and dried, was worn for ten days next the skin below a linen shirt. It was then washed in pure water, and the aqueous liquor was distilled in a retort. The liquid that came over had the smell of sweat, and contained a small quantity of acetic acid. The liquid remaining in the retort, when sufficiently concentrated, assumed the appearance of an acid syrup, which contained common salt; but no salt of lime. It was sparingly precipitated by infusion of nut-galls. Thenard concluded, from his experiments, that the matter of perspiration, besides water, common salt, and acetic acid, contains a little phosphate of soda, traces of phosphate of lime and of iron, and an animal substance precipitated by infusion of nut-galls; probably albumen.

The most recent experiments on the matter of perspiration have been made by Anselmino.§ He plunged his arm into a glass jar, and luted the mouth of it to the arm below the shoulder. The matter perspired condensed on the inside of the glass as in Cruikshanks's experiment, and in six hours he collected a table-spoonful of it. He divided the liquor thus obtained into three portions, and subjected them to the following trials:

1. One portion was mixed with a drop of sulphuric acid and then evaporated to dryness. This residue was mixed with a little caustic potash, and a glass rod dipped in muriatic acid was held over it. Evident fumes of sal-ammoniac made their appearance; showing that ammonia existed as one of the constituents of matter of perspiration.

* Cruikshanks on Insensible Perspiration, p. 93. † Ibid. p. 92.
‡ Ann. de Chim. lix. 262. § Berzelius, Traité de Chimie, vii. 328.

2. A second portion was digested over oxide of lead, and the digestion continued in an open vessel till all the liquid had been driven off. The dry residue being moistened with sulphuric acid, fumes of acetic acid were given out recognizable by the smell.

3. Lime-water was added drop by drop to the third portion. It became muddy, and carbonate of lime was deposited. From these experiments Anselmino concluded that the matter of perspiration contains acetate of ammonia and carbonic acid.

Collard de Martigny assures us that the skin not only gives out carbonic acid gas, but also hydrogen gas and azotic gas, though in very minute quantity.* But how far these statements are correct we do not at present know.

When the temperature of the body is increased either by exposure to a hot atmosphere, or by violent exercise, the matter of perspiration not only increases in quantity, but even appears in a liquid form. This is known by the name of *sweat*. This sweat serves a very important purpose. No sooner is it thrown on the surface of the skin than it begins to evaporate, absorbs heat, and thus the temperature of the body is prevented from rising. This is the reason that animals can endure a much higher temperature without injury than could have been supposed. The experiments of Tillet, and the still more decisive experiments of Fordyce and his associates, are well known. These gentlemen remained for a considerable time in a room, the atmosphere of which was hotter than boiling water.

Sweat is a transparent and colourless liquid, having a saline taste, and yielding, when evaporated, crystals of common salt. According to Berzelius, it contains the same salts as those which exist in the acid liquor obtained from animal muscle by expression; namely, lactates of potash, soda, lime, and magnesia, together with common salt, sal-ammoniac, and traces of chloride of potassium. It contains also traces of phosphate of soda and phosphate of lime. It contains also a small quantity of animal matter insoluble in alcohol.

Anselmino examined a quantity of sweat collected by sponges from the body of a man made to sweat abundantly in a hot stove. The liquid thus obtained was muddy, probably from small portions of the epidermis detached by the friction. It had a peculiar smell, varying in intensity in different individuals. A por-

* Berzelius, Traité de Chimie, vii. 325.

tion of it was filtered and distilled over the steam-bath. The liquid that passed into the receiver contained acetate of ammonia.

When the liquor of sweat was evaporated to dryness it left from a half to one and a-quarter per cent. of dry residue. This residue being treated with alcohol of 0·833, a portion remained undissolved. When the alcoholic solution was evaporated to dryness there remained an extractive matter mixed with a great number of saline crystals. From this matter absolute alcohol separated an acid extractive substance, containing, according to Anselmino, acetic acid, acetate of potash, and an animal matter precipitable by infusion of nut-galls. The portion of matter insoluble in absolute alcohol consisted of common salt with a little chloride of potassium, and an animal substance not precipitable by chlorine, chloride of tin, nor corrosive sublimate.

The portion of dried sweat left by alcohol is almost all soluble in warm water, a little deep-gray powder only remaining. It seems to be a mixture of epidermis and phosphate of lime. When burnt it leaves a bulky ash, consisting of phosphate of lime, mixed with a small quantity of carbonate of lime. The portion dissolved in the warm water contains sulphates, and an animal matter precipitated by chloride of tin, and by infusion of nut-galls. Chlorine occasions no immediate precipitate; but in twenty-four hours white flocks separate from the liquid.

According to the analysis of Anselmino 100 parts of the dry residue from sweat are composed as follows:—

Matters insoluble in water and alcohol, (mostly salts of lime,) .	2
Animal matter soluble in water, and not in alcohol, with sulphates,	21
Matters soluble in weak alcohol, common salt, and animal extract,	48
Matters soluble in absolute alcohol, animal extract, lactic acid and lactates,	29
	100

Anselmino found, likewise, that 100 parts of the dry residue of sweat when burnt leave 22·9 of ashes, containing carbonate, sulphate, and phosphate of soda; a little of the same acids combined with potash and common salt, all soluble in water. Be-

sides phosphate and carbonate of lime, and a trace of peroxide of iron, which are insoluble in water. *

Anselmino found that the sweat, during a fit of the gout, contained more ammonia and saline matter than when in a state of health. He found, also, that a critical *sweat*, during a rheumatic fever, contained a good deal of albumen.

If any conclusion can be deduced from the smell, sweat in different parts of the body is not identical. That of the feet has quite a different smell from that of the arm-pits; while that of the groin in fat persons has often the smell of butyric acid.

Little is known respecting the perspiration and sweat of the inferior animals. It is well known that the genera of quadrupeds belonging to the *dog* and the *cat* tribe do not perspire at all. In ruminating animals and pachydermata, on the contrary, perspiration is abundant. Anselmino has examined the crusts of dried sweat, which may be separated from the skin of a horse by the brush. Being digested in hot water a pulverulent matter remained undissolved. The solution was evaporated to dryness, and the residue digested in alcohol of 0·833. The solution obtained gave, when evaporated, a brown extract filled with saline crystals. Absolute alcohol dissolved from it an acid extractive matter holding in solution a combustible salt of potash. Hence it seems to be of the same nature with the matter obtained from human sweat by a similar process. The absolute alcohol left common salt mixed with an extractive matter, having a strong odour of a horse.

The portion of the residue left undissolved by the alcohol of 0·833 dissolved in water, to which it communicated a brown colour. Besides common salt and sulphate of soda, it contained an animal matter, precipitated by infusion of nut-galls, and by chlorine; by the last only, after an interval of several days. It was neither precipitated by nitric acid, ammonia, nor corrosive sublimate.

The portion of residue of sweat insoluble in alcohol and water, Anselmino considered as coagulated albumen. Fourcroy had announced the presence of urea in the sweat of the horse, but Anselmino could discover no trace of it. The ashes from the dried sweat of the horse consist of sulphates of potash and soda, common salt, and chloride of potassium; it contains

* Berzelius, Traité de Chimie, vii. 326.

neither carbonate nor phosphate of an alkali, but a considerable quantity of phosphates of lime and magnesia, with traces of peroxide of iron.

Henri and Chevalier extracted by alcohol and water the matter of respiration from the hair of cows.* They obtained,

1. A fatty matter.
2. A brownish-black matter.
3. A bitter substance soluble in water.
4. A yellow colouring matter, soluble in alcohol and water.
5. Carbonate and hippurate of soda.

Dr Donné assures us that, in a state of health, the skin and the matter of perspiration is always acid.† Berthollet had observed this many years ago, and concluded that the acid present was the phosphoric. ‡

Thenard obtained *acetic* acid, and Berzelius has rendered it probable that the true acid of sweat is the *lactic*. Though dogs and cats do not sweat, yet their skin, according to Donné, is always acid, while that of rabbits and horses is alkaline. Donné has observed that the matter of perspiration frequently becomes alkaline during disease, especially during those of the chronic kind.§

CHAPTER XX.

OF THE LIQUOR OF THE AMNIOS.

The fœtus in the uterus is enveloped in a peculiar membrane or covering, to which anatomists have given the name of *amnios*. Within this amnios there is a liquid, distinguished by the name of *liquor of the amnios*, which surrounds the fœtus. This liquid in women is a fluid of a slightly milky colour, a faint but not disagreeable smell, and a saltish taste. The white colour is owing to a curdy matter suspended in it, for it may be rendered transparent by filtration.

Its specific gravity, as determined by Vauquelin and Buniva, is 1·005.‖ These chemists analyzed it in 1800. It was again

* Jour. de Pharm. xxv. 422.
† Ann. de Chim. et de Phys. lvii. 401.
‡ Jour. de Phys. xxviii. 275.
§ Ann. de Chim. et de Phys. lvii. 401.
‖ Ann. de Chim. xxxiii. 270.

analyzed by Dr Bostock about the year 1812,* and by Fromherz and Gugert in 1827.†

Fromherz and Gugert describe it as yellow, muddy, and having a slight taste and smell. When perfectly fresh, it reddens turmeric paper, but the red stain disappears as the paper dries, showing that the free alkali present is ammonia. When evaporated to dryness, it left, according to Vauquelin and Buniva, 1·2 per cent., according to Dr Bostock, 1·66, and according to Fromherz and Gugert, 3 per cent. of residue.

It is coagulated when raised to the boiling point, or when mixed with alcohol. Nitric and muriatic acids throw down from it a copious precipitate, but acetic acid only occasions a slight precipitate, which Fromherz and Gugert consider as casein. Caustic potash throws down grayish white flocks. Corrosive sublimate gives a copious precipitate, which becomes red after an interval of some minutes. With infusion of nut-galls it is precipitated abundantly of a light-yellow colour. When the liquor of the amnios is distilled in glass-vessels, till one-fourth of it has passed over into the receiver, we obtain a great deal of carbonate of ammonia and a certain quantity of sulphuret of ammonium. When the distillation is continued, more carbonate of ammonia passes into the receiver, but no more sulphuret of ammonium.

When filtrated *liquor amnii* is treated with caustic potash, phosphate of lime, and lime precipitate, both in combination with an animal matter, by means of which they had been kept in solution. The potash unites with a portion of this matter, which causes these earthy salts to precipitate.

When the liquor of the amnios is evaporated to dryness and the residue treated with alcohol, a yellow extractive substance is dissolved, to which Fromherz and Gugert have given the name of *osmazome*. The insoluble portion consists chiefly of *albumen;* but contains also *casein* and *salivin*. But of the presence of this last substance they have given no evidence. By treating another portion of the liquor amnii in another manner, they obtained *benzoic acid* and *urea*. But the evidence of the presence of these two substances is very incomplete. What they considered as nitrate of urea was not subjected to any examination. They found also in the liquor amnii much common salt; phosphate, sulphate, and

* Schweigger's Jour. xxiii. 407. † Ibid. l. 191.

carbonate of soda; sulphate of lime, and traces of salts of potash.

According to Vauquelin and Buniva, the liquor amnii of a woman was composed of,

Water,	98·8
Albumen, Common salt, soda, Phosphate of lime, lime,	1 2
	100·

According to Dr Bostock, the constituents are,

Water,	97·34
Albumen,	0·16
Uncoagulable matter,	1·10
Salt,	1·40
	100·00

Four specimens of liquor amnii examined by Dr Rees, extracted from four individuals in the 7½ month of gestation, contained the same constituents. Specific gravity from 1·0086 to 1·007. They all contained urea as a constituent. The caseous matter floating in the liquid contained cholesterin. The salts are the same as those of blood. The following table shows the constituents of one specimen:

Specific gravity 1·008, strongly alkaline.

Water,		984·98
Albumen with trace of fatty matter,		1·80
Extract soluble in water,	Salts, 2·80, Organic matter chiefly albumen, 3·22,	6·02
Do. soluble in water and alcohol,	Salts, 2·80, Organic matter chiefly lactic acid, urea, 4·4,	7·20
		100·00*

Fromherz and Gugert did not attempt a quantitative analysis of liquor amnii, but merely to determine the different constituents which it contained.

* Phil. Mag. (3d series,) xiii. 305.

While the fœtus is in the uterus, a curdy-like matter is deposited on the surface of the skin and on particular parts of the body.

This matter is often found collected in considerable quantities. It is evidently deposited from the liquor of the amnios; and of course must exist in that liquor. It was subjected to a chemical examination by Vauquelin and Buniva, and also by Fromherz and Gugert.

Its colour is white and brilliant, it has a soft feel, and very much resembles new-made soap. It is insoluble in water, alcohol, and oils. Pure alkalies dissolve it partially, and convert it into a kind of soap. On burning coals it decrepitates, becomes dry and black, gives out oily vapours, and leaves a residue very difficult to incinerate. From these properties Vauquelin and Buniva were led to consider it as a kind of *fat*.

Fromherz and Gugert digested it repeatedly in ether, and left the ether to spontaneous evaporation. Brilliant white plates were deposited, which had neither taste nor smell. They were insoluble in water, but dissolved in boiling alcohol, and the solution was neutral. They did not melt, though heated to 212°, and when decomposed no carbonate of ammonia was given off. When boiled with potash ley this substance could not be converted into soap. Fromherz and Gugert consider it as *cholesterin*.

The residue left by the ether was treated with cold water, and as that substance did not seem to act, the water was raised to the boiling temperature. The solution was yellowish and quite transparent. Being evaporated to dryness the residue was insoluble in alcohol. It had an alkaline reaction and possessed the characters of salivin. When incinerated it left a little carbonate of soda.

When the curdy matter is digested directly in water, without being previously treated with ether, salivin and carbonate of soda are dissolved; but no albumen.

After the curdy matter has been treated with ether and boiling water, a white flocky matter remains, which possesses the following characters: When heated it gave out much carbonate of ammonia. It was insoluble in alcohol, ether, and cold water. When boiled about an hour in water a small portion of it was dissolved. The solution was precipitated by infusion of nut-galls, nitrate of silver, and protonitrate of mercury. Caustic alkali, while cold, scarcely dissolves it; but when it is boiled in dilute

alkaline ley it is partially dissolved, and the solution is precipitated by muriatic acid white. Sulphuric acid mixed with twice its weight of water gives this substance a dark-red colour, but does not dissolve it. From these characters Fromherz and Gugert conclude that the insoluble portion of the caseous matter from *liquor amnii* is *albumen.*

Thus it appears that the constituents of the caseous matter are,

Cholesterin.	Carbonate of soda.
Salivin.	Phosphate of lime.
Coagulated albumen.	

II. The *liquor amnii* of the cow was also examined by Vauquelin and Buniva. But there is reason, from the subsequent experiments of Lassaigne, to conclude that these chemists confounded together in their experiments the liquor of the amnios and of the allantois. We have, however, an examination of the true *liquor amnii* of the cow by Lassaigne in 1821,* and by Prout† in 1815.

The *liquor amnii* examined by Dr Prout had been taken from the uterus of a cow slaughtered in an early period of her gestation. It had a yellowish colour, with the appearance of very minute shining particles floating in it. Smell fragrant, something like that of new milk or butter. Taste bland and sweetish like fresh whey. Foamed a good deal when shaken. Did not affect litmus or turmeric paper. Specific gravity 1·013. It contained a very sensible quantity of the sugar of milk, which separated in crystals from it when it had been concentrated by evaporation. It coagulated partially by heat; some flakes fell, and the liquid was left nearly transparent and colourless. Acetic acid produced no coagulation, and prevented it from coagulating by heat. Hence it contained albumen. Chloride of barium produced a copious white precipitate. Dr Prout analyzed it and obtained,

Water,	977·0
Albumen,	2·6
Substances soluble in alcohol,	16·6
Substances soluble in water, chiefly sulphate of soda? and other salts. Also sugar of milk,	3·8
	1000·0

* Ann. de Chim. et de Phys. xvii. 300. † Annals of Philosophy, v. 416.

The principles soluble in alcohol were of a brown colour; and seemed to consist in part of the lactates; but chiefly of a peculiar substance, having considerable resemblance in its properties to the external brown parts of roasted veal.

The *liquor amnii* of the cow examined by Lassaigne differed somewhat in its properties from the preceding, owing probably to the different periods of gestation at which it was procured. It had a yellowish colour, was viscid and sensibly alkaline. The constituents extracted from it by Lassaigne (not reckoning the water) were the following:

Albumen.	Chloride of potassium.
Mucus.	Carbonate of soda.
Yellow matter of bile.	Phosphate of lime.
Common salt.	

III. Lassaigne likewise analyzed the *liquor amnii* of a mare, and obtained from it the following substances:*

Mucus.	Common salt.
Albumen, (little.)	Chloride of potassium.
Osmazome.	Carbonate of soda.
Yellow matter.	Phosphate of lime.

CHAPTER XXI.

OF THE LIQUOR OF THE ALLANTOIS.

The fœtus in the uterus is enveloped in several successive membranes. The outermost is called the chorion. Below this, especially in quadrupeds, is a second membrane called the *allantois;* while the third or innermost membrane is called the *amnios.* Both the allantois and the amnios contain a quantity of liquid. The characters and constituents of the *liquor amnii* have been given in the last chapter. At present we shall treat of the liquor of the allantois.

The only chemist, so far as I know, who has turned his attention to this subject, is Lassaigne. In 1821, he published an analysis of the liquor of the allantois of the cow and the mare.† Vauquelin and Buniva may have examined the liquor of the al-

* Ann. de Chim. et de Phys. xvii. p. 303. † Ibid. xvii. 296, 303.

lantois of the cow; but it is more probable that in their analysis the two liquors had been mixed together.

The liquor of the allantois of the cow is transparent, has a fawn-yellow colour, and a taste slightly bitter and saline. It reddened litmus-paper, and had a specific gravity of 1·0072. When evaporated in a porcelain basin, a brownish pellicle formed on its surface, and precipitated in flocks. This substance possessed the following properties:

It was insoluble in water, alcohol, and diluted acids. It dissolved readily in alkalies. When ignited it blackened, swelled up, and emitted the odour of burning horn. When incinerated it left a grayish ash composed of phosphates of lime and magnesia. These characters show that the coagulated matter was albumen.

When the liquid was evaporated to the tenth part of its original volume, and left in a cool place for twelve hours, it did not deposit crystals. Being now treated with boiling alcohol, it was separated into two portions: the one brown and viscid did not dissolve; while the other, which was brownish-yellow, dissolved in the alcohol.

When the alcoholic solution was evaporated it left a yellowish-brown acid matter, having the smell and taste of beef-tea. Being left at rest for twenty-four hours confused crystals were deposited, which were white, and had a pearly lustre, and which were easily freed from the colouring matter by washing them in cold water. These crystals constituted the substance called *amniotic* acid by Vauquelin and Buniva. The name was changed to *allantoic* acid by Lassaigne, and to *allantoin* by Wöhler and Liebig, because they did not find it to possess acid characters.* The alcoholic extract from which the allantoin had been separated still reddened litmus-paper. It had a deep-brown colour, and a smell and taste similar to that of the juice of roasted meat. Lassaigne considered it as a mixture of osmazome and lactic acid. When calcined in a crucible it left a grayish-white ash, partly soluble in water. The liquid being evaporated gave crystals of common salt mixed with a little carbonate of soda. The portion of the ashes insoluble in water was phosphate of lime. Besides these constituents the portion dissolved in alcohol contained some sal-ammoniac.

* The properties of this substance have been described in the Chemistry of Vegetable Bodies, p. 212.

The portion of the extract insoluble in alcohol was dissolved in water, and the solution left in repose in a cold place; but no crystals were deposited even after an interval of several days. It was not precipitated by muriatic acid; nitrate of barytes threw down a copious white powder insoluble in nitric acid; lime-water occasioned a white flocculent precipitate, while infusion of nut-galls and acetate of lead threw down copious coloured precipitates. When incinerated, it left a good deal of sulphate of soda and phosphate of soda, with some phosphates of lime and magnesia. The following were the substances extracted from the liquor of the allantois of a calf by Lassaigne:

Albumen.	Sal-ammoniac.
Osmazome.	Common salt.
Mucus.	Much sulphate of soda.
Allantoin.	Phosphate of soda.
Lactic acid and lactate of soda.	Phosphates of lime and magnesia.

Lassaigne also examined the liquor of the allantois of a mare, but could detect in it no allantoin. The following were the substances which he obtained from it:

Mucus.	Common salt.
Albumen.	Chloride of potassium.
Osmazome.	Much sulphate of potash.
Lactic acid.	Phosphates of lime and magnesia.

M. Lassaigne had already, in 1819, examined the soft white viscid matter found in the liquor of the allantois of a calf, especially towards the period of gestation, and known to veterinary surgeons by the name of *hippumanes*.*

Cold water extracted from it only a little albumen and common salt. Alcohol and ether were incapable of dissolving any part of it. When heated in caustic potash, it dissolved, with the exception of a white crystalline powder, which constituted 27 per cent. of the original matter. The matter dissolved by the potash being thrown down by an acid possessed the characters of mucus. The white powder was oxalate of lime.

* Ann. de Chim. et de Phys. x. 200.

CHAPTER XXII.

OF PUS.

The liquid called *pus* is secreted from the surface of an inflamed part, and usually moderates and terminates the inflammation. It assumes different appearances according to the state of the sore. When it indicates a healing sore, it is called *healthy* or *good-conditioned* pus. Unfortunately this liquid has not hitherto been subjected to a rigid chemical examination.

The following are the only two analyses of pus made by any modern chemist, and they are imperfect: I. That of pus from an empyema by MM. Wilhelm and Martius in 1837. The patient was a miller in the hospital of Erlangen, who had pleuropneumonia, with hepatization of the left lobe of the lungs. The pus was extracted by an operation, and amounted to 153 German pounds.*

It was destitute of smell, thick in its consistence, and had a dirty greenish-gray colour. Being examined by reagents, the following phenomena were observed:

1. Litmus-paper was slightly reddened.

2. When agitated with ether, the colour became darker, and the ether assumed a yellowish colour.

3. When mixed with absolute alcohol, many fine white flocks separated, which could not be again taken up by agitation. The alcoholic liquid gradually assumed a yellowish colour.

4. When dropped into water, it sank to the bottom, and by agitation it constituted a muddy liquid.

5. Being mixed with an excess of caustic ammonia, it was changed into a muddy liquid, from which white flocks were precipitated. The supernatant liquid was greenish-yellow.

6. An excess of acetic acid gave a muddy liquid having a peach-blossom colour.

7. Nitric acid added in excess gave a muddy yellowish-green liquid.

8. When heated in a platinum spoon, it swelled very much. When evaporated to dryness, it left a black residue, and gave out a smell like that of burning flesh.

* Ann. der Pharm. xxiv. 79.

To determine its composition, it was mixed with ether, agitated and raised to the boiling temperature. The ether was then allowed to cool and passed through a filter, which it did very slowly. The etherial solution was yellowish, and had a specific gravity of 1·11155 at the temperature of 50°. When examined by reagents, it exhibited the following properties:

1. Caustic ammonia threw down a few white flocks.
2. Nitric acid; no apparent change.
3. Chloride of platinum threw down yellowish flocks.
4. Acetate of silver, copious white flocks redissolved by the addition of ammonia.
5. Chloride of gold threw down a yellowish precipitate.
6. Nitrated suboxide of mercury threw down an abundant yellowish-white precipitate in flocks.
7. Neutral persulphate of iron a reddish-yellow precipitate.
8. Acetate of lead a copious precipitate in white flocks.
9. Nitrate of barytes a white precipitate.
10. Tincture of nut-galls a very copious reddish-yellow precipitate.
11. Isinglass produced no change.

After these trials, the etherial solution was evaporated to the consistence of an extract in a gentle heat. It was yellowish-brown, and smelled like soup. It could not be made perfectly dry over the water-bath. A portion of it was burnt in a porcelain crucible. It emitted the smell of burning horn. The charry residue was digested in dilute muriatic acid. It dissolved with effervescence, except a little charcoal. The solution was not affected by sulphuretted hydrogen. Chloride of ammonium and ammonia being added in excess, a copious white precipitate fell, which was chiefly phosphate of lime. Some lime was also present, which was thrown down by oxalate of ammonia. It contained also a little magnesia. They suspected likewise the presence of soda. This was not fully proved, but the presence of potash was ascertained. When treated with caustic potash, ammonia was given out. Thus the bases found in the pus were lime, magnesia, potash, soda, and ammonia. But the ammonia might have been formed by the action of the potash on the organic matter of pus.

The acid which existed in the pus was a mixture of phosphoric and muriatic. It contained no sulphuric acid nor nitric acid.

To determine whether it contained lactic acid, so common in animal fluids, the dried extract was digested in alcohol of 0·870. The alcohol, after being separated by the filter, was strongly coloured, and reacted as an acid. It was mixed with sulphuric acid diluted with alcohol, which caused a crystalline precipitate of sulphate of soda and potash. The filtered liquid was digested with carbonate of lead, till it ceased to be precipitated by chloride of barium. It was now distilled, after separating the lead by sulphuretted hydrogen. What came over contained no acid, showing the absence of acetic acid from the pus. What remained in the retort had the consistency of a syrup, was of a dark-brown colour, and strongly reddened litmus-paper. It was diluted with water, and boiled with carbonate of zinc, as long as any carbonic acid was disengaged. The excess of oxide of zinc was then removed by the filter. The liquid, after being digested with some animal charcoal, was evaporated, and left a crust of lactate of zinc, which is exceedingly soluble in water. The oxide of zinc was thrown down by carbonate of potash, the potash by tartaric acid, and the excess of tartaric acid by carbonate of lead. The lead being removed by sulphuretted hydrogen and the liquid evaporated, a colourless acid syrup was obtained, possessing all the properties of lactic acid.

The slimy matter not taken up by the alcohol contained fat, gelatin, and some albumen.

A portion of pus was left in contact of ether for six months. It was converted into a cheesy magma, over which the yellow ether floated. The ether contained in solution much yellow fat of the consistence of butter.

The present opinion of physiologists is, that the globules constituting pus are nothing else than the globules of blood modified by the inflammatory process. Many experiments have been made by M. Gendrin and Mr Gulliver to prove the truth of this opinion.*

II. Dr Becquerel made an imperfect analysis of pus from an abscess, the result of which was as follows :† It was white, with a shade of yellowish-green, opaque, very thick and viscid, and having a peculiar smell. With water it formed an emulsion, from which the pus precipitated very slowly to the bottom in white clots. The water is clear and limpid, but it had dissolved

* Phil. Mag. (third series), xiii. 198. † Semeiotique des Urines, p. 108.

the salts of the pus, consisting of sulphates, phosphates, and chlorides, and also a notable quantity of albumen, coagulated by nitric acid or heat. With ammonia pus forms a kind of soap. When agitated with ether and the mixture left at rest, it was divided into two strata. The undermost was clear and transparent, and contained the salts and albumen of the pus; the uppermost, thick and thready, contained the solution of the fatty matters and the globules. When examined by the microscope it is found to contain a great number of globules, having a diameter varying from $\frac{1}{1250}$th to $\frac{1}{1889}$th of an inch. When treated by acetic acid and examined by the microscope, it was found that the outermost coat of the globules had been dissolved, leaving the internal nucleus, which often subdivided itself into several smaller globules. It dissolved completely, though slowly, in ammonia. Becquerel gives the following characters to enable us to distinguish mucus from pus.

Mucus.	Pus.
1. Viscid.	1. Viscid and thick.
2. Transparent or opaline.	2. Opaque, yellowish-white.
3. Neutral.	3. Alkaline.
4. Very little fatty matter.	4. Much fatty matter.
5. Very little altered by ammonia.	5. Made gelatinous by ammonia, and finally dissolved.
6. Charred in a spirit-lamp, giving out occasionally a slight flame.	6. Burns in a spirit-lamp with a lively flame.
7. Before the microscope, composed of thin plates, with occasional globules.	7. Do. Globules of a diameter from $\frac{1}{1250}$th to $\frac{1}{1889}$th of an inch in diameter.

CHAPTER XXIII.

OF ANIMAL POISONS.

SEVERAL animals are furnished with liquid juices of a poisonous nature, which, when poured into fresh wounds, occasion the disease or death of the wounded animal. Serpents, bees, scorpions, spiders, are well known examples of such animals. The chemical properties of these poisonous juices deserve peculiar at-

tention; because it is only from such an investigation that we can hope to explain the fatal changes which they induce on the animal economy, or to discover an antidote sufficiently powerful to counteract their baneful influence. Unfortunately the task is difficult, and perhaps surpasses our chemical powers. For the progress already made in the investigation, we are indebted chiefly to the labours of Fontana.

1. The poison of the viper is a yellow liquid, which lodges in two small vesicles in the animal's mouth. These communicate by a tube with the crooked fangs, which are hollow and terminate in a small cavity. When the animal bites, the vesicles are squeezed, and the poison forced through the fangs into the wound. This structure was partly observed by Redi, an Italian philosopher; and his discoveries were completed and confirmed by the experiments and observations of Francini,* Tysson,† Mead,‡ and Fontana.

This poisonous juice occasions the fatal effects of the viper's bite. If the vesicles be extracted, or the liquid prevented from flowing into the wound, the bite is harmless. If it be infused into wounds made by sharp instruments, it proves as fatal as when introduced by the viper itself. Some of the properties of this liquid were pointed out by Mead; but it was Fontana who first subjected it to a chemical examination, sacrificing many hundred vipers to his experiments. The quantity contained in a single vesicle scarcely exceeds a drop.

It has a yellow colour, has no taste; but when applied to the tongue occasions numbness. It has the appearance of oil before the microscope, but it unites readily with water. It produces no change on vegetable blues.

When exposed to the open air, the watery part gradually evaporates, and a yellowish-brown substance remains, which has the appearance of gum-arabic. In this state it feels viscid like gum between the teeth; it dissolves readily in water, but not in alcohol; and alcohol throws it down in a white powder from water. Neither acids nor alkalies have much effect upon it. It does not unite with volatile oils nor sulphuret of potash. When heated it does melt, but swells, and does not inflame till it has become black. These properties are similar to the properties of gum,

* New Abridg. of the Phil. Trans. ii. 8. † Phil. Trans. Vol. xii.

‡ Mead on Poisons, p. 35.

and indicate the gummy nature of this poisonous substance. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results.

From the observations of Dr Russel, there is reason to believe that the poisonous juices of the other serpents are similar in their properties to those of the viper.

This striking resemblance between gums and the poison of the viper, two substances of so opposite a nature in their effects upon the living body, is a humiliating proof of the small progress we have made in the chemical knowledge of these intricate substances. The poison of the viper, and of serpents in general, is most hurtful when mixed with the blood. Taken into the stomach it kills if the quantity be considerable. Fontana has ascertained that its fatal effects are proportional to its quantity, compared with the quantity of the blood. Hence the danger diminishes as the size of the animal increases. Small birds and quadrupeds die immediately when they are bitten by a viper; but to a full-sized man the bite seldom proves fatal.

Ammonia has been proposed as an antidote to the bite of the viper. It was introduced in consequence of the theory of Dr Mead, that the poison was of an acid nature. The numerous trials of that medicine by Fontana robbed it of all its celebrity; but it has been lately revived and recommended by Dr Ramsay as a certain cure for the bite of the rattlesnake.*

2. The common *toad* (*Rana bufo*) has been considered as poisonous by the common people in all ages. But the opinion was rejected by naturalists as a vulgar prejudice till the subject was investigated by Dr Davy.†

This poisonous liquid is seated chiefly in the integuments, in follicles, in the cutis vera beneath the cuticle, and the coloured rete mucosum. These follicles are largest and most numerous near the shoulders and about the neck of the animal; yet they are pretty generally distributed, and even on the extremities. Pressure being applied to the skin a yellowish thick fluid exudes,

* Phil. Mag. xvii. 125. The reader will find an interesting dissertation on the different remedies applied to the cure of the rattlesnake in the Amer. Trans. Vol. iii. p. 100, by Dr Smith Barton. The observations of Fontana in his treatise on poisons deserve particular attention.

† Phil. Trans. 1826, p. 227.

and occasionally spurts to a considerable distance. Dr Davy found it possessed of the following properties:

The greater part of it is soluble in alcohol and water. The aqueous solution is slightly viscid, and does not pass easily through a common filter. It is not precipitated by acetate of lead, and only very slightly by corrosive sublimate. When the aqueous or alcoholic solution is evaporated to dryness, it leaves a yellow transparent substance, having a slight but peculiar smell, and a slightly bitter and very acrid taste, acting on the tongue like the extract of aconite prepared in vacuo. It even occasions a smart sensation when applied to the skin of the hand, and its effect lasts two or three hours. When heated it readily melts, burns with a bright flame, and does not emit an ammoniacal smell. It neither reacts as an acid nor an alkali. Caustic ammonia dissolves it. The solution remains acrid. Nitric acid also dissolves it, and the solution has a purple colour. When neutralized by an alkali the solution is but slightly acrid, and seems to have undergone partial decomposition.

Dr Davy conceives that the small portion of the poison of the toad which is insoluble in water and alcohol, is a variety of albumen. But he does not state the reasons on which this opinion is founded.

Notwithstanding the acridity of this substance, it would appear from Dr Davy's experiments that it is not injurious when introduced into the blood. A chicken punctured with a lancet dipt in it received no injury. Dr Davy says that he detected a notable quantity of it in the bile of the toad, in the viscid liquid lubricating the tongue, and in the blood and urine of the animal. But he does not mention the characters by which its presence in these liquids was recognized.

Dr Davy conceives that this liquor, (the venomous nature of which does not seem well established by his experiments,) may serve to protect the animal from the attacks of carnivorous animals. He thinks also that its secretion may contribute to the discharge of carbon from the blood; and conceives that this opinion is strengthened by a peculiarity in the distribution of the pulmonary artery, which he describes.

The poisonous liquid of the toad had been subjected to experiment by M. Pelletier in 1817.* His results agree, on the

* Jour. de Pharmacie, iii. 537.

whole, with those of Dr Davy, though in some circumstances they differ. He found that when exposed to the air it soon became solid, and that if it had been put into a watch-glass it might in a few minutes be taken off under the form of transparent scales. It was exceedingly acrid, both when liquid and solid, and reacted strongly as an acid. With water it formed an emulsion. Cold alcohol had little action on it; but it dissolved a portion when assisted by heat, and assumed a fawn-colour. The portion undissolved was white and destitute of taste and smell. It resembled, according to Pelletier, the gelatinous membranes.

The alcoholic solution scarcely reddened litmus-paper, and lost that property entirely when evaporated. As the alcohol was driven off an oily matter separated, which became solid on cooling. This matter was insoluble in water, little soluble in ether; but very soluble in alcohol. Its taste was very bitter; but it was neither acrid nor caustic. It reacted slightly as an alkali. The acid of the poison of the toad appears from Pelletier's experiments to be very volatile and only partially combined with a base. Hence probably the reason why it was not detected by Dr Davy.

The gelatinous matter of the poison was insoluble in cold water; but soluble in hot water, to which it communicated a gelatinous consistence. But, as it was neither precipitated by chlorine nor by infusion of nut-galls, it is obvious that it was a different substance from either *collin* or *chondrin*.

3. The venom of the bee and the wasp is a liquid contained in a small vesicle forced through the hollow tube of the sting into the wound inflicted by that instrument.* From the experiments of Fontana we learn that it bears a striking resemblance to the poison of the viper. That of the bee is much longer in drying when exposed to the air than the venom of the wasp.

4. The poison of the scorpion resembles that of the viper also. But its taste is hot and acrid, which is the case also with the venom of the bee and the wasp.

5. No experiments upon which we can rely have been made upon the poison of the spider tribe. From the rapidity with which these animals destroy their prey, and even one another, we cannot doubt that their poison is sufficiently virulent.†

* See a curious account of the structure of the sting by Dr Hooke in his Micrographia.

† Dr Mead's romantic account of the bite of the tarantula will entertain the reader. See Mead on Poisons, p. 57.

CHAPTER XXIV.

OF FECES.

The excrementitious matter of animals, evacuated *per anum*, consists of all that part of the food which cannot be employed for the purposes of nutrition, considerably altered, at least in part, and mixed or united with various bodies employed during digestion to separate the useless parts of the food from the nutritious. An accurate examination of these matters has long been wished for by physiologists, as likely to throw much new light on the process of digestion. For if we knew accurately the substances which were taken into the body as food, and all the new substances which were formed by digestion: that is to say, the component parts of chyle and of excrement, and the variation which different kinds of food produce in the excrement, it would be a very considerable step towards ascertaining precisely the changes produced on food by digestion.

Some of the older chemists had turned their attention to the excrements of animals;* but no discovery of importance rewarded them for their disagreeable labour. Vauquelin has ascertained some curious facts respecting the excrementitious matter of fowls. In the summer of 1806, a laborious set of experiments on human feces was published by Berzelius, undertaken, as he informs us, chiefly with a view to elucidate the function of digestion.† About two years before, Thaer and Einhof had published a similar set of experiments on the excrements of cattle; made chiefly to discover, if possible, how they act so powerfully as manure.‡ I shall in this chapter give a view of the results obtained by these different chemists.

I. The appearance of human feces requires no particular detail. Their colour is supposed to depend upon the bile mixed with the food in the alimentary canal. When too light, it is supposed to denote a deficiency of bile; when too dark, there is supposed to be a redundancy of that secretion. The smell is fetid and peculiar, which after some time gradually changes in-

* Van Helmont's Custos Errans, Sect. vi. Opera Helmont, p. 14. Neumann's Works, p. 585.

† Gehlen's Jour. vi. 509.

‡ Ibid. iii. 276.

to a sourish odour. The taste is sweetish bitter. The colour of vegetable blue infusions is not altered by fresh feces, indicating the absence of any uncombined acid or alkali.*

1. The consistency of human feces varies considerably in different circumstances; but at a medium, they may be stated to lose three-fourths of their weight when dried upon a water-bath.†

2. They do not mix readily with water; but by sufficient agitation and maceration, they may be diffused through it. The liquid, in this state, being strained through a linen cloth, leaves a matter of a grayish-brown colour, retaining a peculiar odour, which adheres long and obstinately to all those substances that come in contact with this residue. When dried, this substance exhibits the remains of vegetable matters used in food, and perhaps also of some animal matters. Its quantity amounts to about seven per cent. of the feces.‡

3. The strained liquid deposited, on standing, a yellowish-green slimy matter, which was separated by the filter. It amounted when dry to fourteen per cent. of the feces employed. From the numerous experiments of Berzelius upon this matter, it appears to be composed chiefly of three substances: 1. A fatty matter, separated by means of alcohol, which possesses many properties in common with picromel, and which Berzelius considers as that substance a little altered. 2. A peculiar yellow-coloured substance, dissolved by water after the fatty matter is removed. This substance Berzelius compares to gelatin; but it appears to be rather more closely allied to mucus, or, at least, to contain mucus as a constituent. It dissolves in water, but not in alcohol; tannin makes its solution muddy, but occasions no precipitate; acetate of lead occasions a copious white precipitate, but does not deprive the solution of its yellow colour. It soon runs to putrefaction, exhaling the odour of putrid urine. 3. A greenish-gray residue, insoluble both in water and alcohol, and leaving, when incinerated, some silica and phosphate of potash.§

4. The liquid which passed through the filter was at first light-yellow; but by exposure to the air it became brown, which gradually deepened in colour, till the solution grew at last muddy. When concentrated by evaporation, small transparent crystals made their appearance: which proved, on examination, to be crystals of ammonia-phosphate of magnesia. The solution, on

* Gehlen's Jour. vi. 512. † Ibid. vi. 535. ‡ Ibid. vi. 513. § Ibid. 526—534.

examination, was found to contain the following substances: 1. Albumen, which was obtained by mixing the concentrated solution with alcohol. The precipitate consisted of a mixture of albumen and phosphoric salts. The albumen obtained from 100 parts of feces amounted only to 0·9 parts. 2. Bile. By this Berzelius understood a mixture of biliary matter and soda. The presence of this substance was inferred from the nature of the precipitate obtained by acids, and the salt of soda obtained by evaporating the residue. The quantity contained in 100 parts of feces was 0·9. 3. A peculiar substance, of a reddish-brown colour, soluble both in water and alcohol. Acids give it an intense brown colour. A small quantity of tannin throws it down of a red colour and in a pulverulent form; a large quantity throws it down in grayish-brown flakes. It is precipitated by muriate of tin, nitrate of silver, and acetate of lead. When heated it melts and emits the smell of ammonia. It leaves behind it, when burnt, traces of soda and of phosphoric salts. Berzelius supposes that this substance is formed from the biliary matter, by some change which it undergoes after the feces are exposed to the air. The quantity of it obtained from 100 part of feces was 2·7 parts. 4. Various salts: these in all, from 100 parts of feces (including the ammonio-phosphate of magnesia), amounted to 1·2 parts. Their relative proportions were as follows:

Carbonate of soda,	35
Common salt,	4
Sulphate of soda,	2
Ammonia-phosphate of magnesia,	2
Phosphate of lime,	4

Such are the constituents of human feces, according to the experiments of Berzelius. The following table exhibits the result of his analysis:*

Water,	73·3
Vegetable and animal remains,	7·0
Bile,	0·9
Albumen,	0·9
Peculiar and extractive matter,	2·7
Salts,	1·2
Slimy matter; consisting of biliary matter, peculiar animal matter, and insoluble residue,	14·0
	100·0

* Gehlen's Jour. vi. 536.

II. The excrementitious matter examined by Thaer and Einhof was that of cattle fed at the stall, chiefly on turnips. It had a yellowish-green colour, a smell somewhat similar to that of musk, and but little taste. Its specific gravity was 1·045. It did not alter vegetable blues, and of course contained no uncombined acid or alkali.

1. Sulphuric acid, when mixed with this matter, developes the odour of acetic acid; but Thaer and Einhof have shown that this acid does not exist in the feces, but is formed by the action of the sulphuric acid.* The pure alkalies, nitric and muriatic acids, produce little change on the feces of cattle, at least when not assisted by heat.

2. When 100 parts are dried on a steam-bath, they leave 28⅛ of solid matter.

3. When eight ounces, or 3840 grains, were diffused through water, they let fall a quantity of sand, weighing 45 grains.

4. The watery solution, being strained through a linen cloth, left 600 grains of a yellowish fibrous matter, which possessed the properties of the fibrous matter of plants.*

5. The liquid, on standing, deposited a slimy substance, which was separated by filtration. It weighed when dry 480 grains. To this matter the feces owe their peculiar colour and smell. It was insoluble in water and alcohol. When heated it smelled like ox bile. It burnt like vegetable matter. Alkalies scarcely affected it. Sulphuric acid developed the odour of acetic acid. Chlorine rendered it yellow. Thaer and Einhof considered this substance as the remains of the vegetable matter employed as food by the cattle; but it is extremely probable that it might contain also a portion of picromel, as Berzelius detected that substance in similar matter from the human feces.

6. The filtered solution passed through colourless, but on exposure to the air became in a few minutes wine-yellow and then brown. When evaporated to dryness it left a brownish matter, of a bitterish taste, and weighing 90 grains. It was soluble in water, insoluble in alcohol, and precipitated from water by that liquid. It was not precipitated by infusion of galls. The solution was found to contain some phosphoric salts. The 90 grains of residue, when heated, burnt like animal matter. They soon ran into putrefaction, exhaling ammonia.†

* Gehlen, iii. 286. † Ibid. iii. 287.

7. When evaporated to dryness and burnt, this excrementitious matter left behind it an ash, which was found (not reckoning the sand) to consist of the following salts and earths in the proportion stated :*

Lime,	12
Phosphate of lime,	12·5
Magnesia,	2
Iron,	5
Alumina with some manganese,	14
Silica,	52
Muriate and sulphate of potash,	1·2

8. Thaer and Einhof made numerous experiments on the putrefaction of cow-dung, both in close vessels and in the open air, from which it would appear that the process resembles closely the putrefaction of vegetable matter; the oxygen of the air being abundantly changed into carbonic acid.†

III. To Vauquelin we are indebted for an analysis of the fixed parts of the excrements of fowls, and a comparison of them with the fixed parts of the food ; from which some very curious consequences may be deduced.

He found that a hen devoured in ten days 11111·843 grains troy of oats. These contained,

Phosphate of lime,	126·509 grains.
Silica,	219·548
	346·057

During these ten days she laid four eggs ; the shells of which contained 98·779 grains phosphate of lime, and 453·417 grains carbonate of lime. The excrements emitted during these ten days contained 175·529 grains phosphate of lime, 58·494 grains of carbonate of lime, and 185·266 grains of silica. Consequently, the fixed parts thrown out of the system during these ten days amounted to,

Phosphate of lime,	274·305 grains.
Carbonate of lime,	511·911
Silica,	185·266
Given out,	971·482
Taken in,	356·057
Surplus,	615·425

* Gehlen, iii. 321.

† Ibid. 295, 313.

Consequently, the quantity of fixed matter given out of the system in ten days exceeded the quantity taken in by 615·425 grains.

The silica taken in amounted to, . .	219·548 grains.
That given out was only, . .	185·266
Remain,	34·282

Consequently, there disappeared 34·282 grains of silica.

The phosphate of lime taken in was .	136·509 grains.
That given out was . .	274·305
	137·796

Consequently, there must have been formed, by digestion, in this fowl, no less than 137·796 grains of phosphate of lime, besides 511·911 grains of carbonate. Consequently, lime (and perhaps also phosphorus) is not a simple substance, but a compound, and formed of ingredients which exist in oat-seed, water, or air, the only substances to which the fowl had access. Silica may enter into its composition, as part of the silica had disappeared; but if so, it must be combined with a great quantity of some other substance.*

These consequences are too important to be admitted without a very rigorous examination. The experiment must be repeated frequently, and we must be absolutely certain that the hen has no access to any calcareous earth, and that she has not diminished in weight; because, in that case, some of the calcareous earth, of which part of her body is composed, may have been employed. This rigour is the more necessary, as it seems pretty evident, from experiments made long ago, that *some* birds, at least, cannot produce eggs unless they have access to calcareous earth. Dr Fordyce found, that, if the canary bird was not supplied with lime at the time of her laying, she frequently died, from her eggs not coming forward properly.† He divided a number of these birds at the time of their laying eggs into two parties: to the one he gave a piece of old mortar, which the little animals swallowed greedily; they laid their eggs as usual, and all of them lived; whereas many of the other party, which were supplied with no lime, died.‡

* Ann. de Chim. xxix. 61.

† On Digestion, p. 25.

‡ Ibid. p. 26.

Vauquelin also ascertained, according to Fourcroy, that pigeons' dung contains an acid of a peculiar nature, which increases when the matter is diluted with water, but gradually gives place to ammonia, which is at last exhaled in abundance.*

IV. The white matter voided by dogs who feed chiefly on bones, was formerly used in medicine under the name of *album græcum*. It has not been examined by modern chemists, but is supposed to consist in a great measure of the earthy part of the bones used as food.†

V. M. Lassaigne,‡ in 1821, made some experiments on the meconium from the fœtus of a calf. He found in it the following substances:

Mucus,	Common salt,
Green matter,	Carbonate of soda,
Yellow matter,	Phosphate of lime.

VI. In the year 1815, Dr Prout examined the excrements of the *Boa constrictor*.§ This substance was solid, of a white colour, inclining to yellow. The fracture was earthy. When it was rubbed against a hard body, it left a white mark like chalk. Its feel was rather more dry and harsh than that of chalk, and it was more friable. The smell was faint and mawkish. The specific gravity, 1·385. It was found composed of,

Uric acid,	90·16
Potash,	3·45
Ammonia,	1·70
Sulphate of potash with trace of common salt,	0·95
Phosphate of lime, Carbonate of lime, Magnesia,	0·80
Animal matter; viz. mucus and a little colouring matter,	2·94
	100·00

These facts were confirmed by Dr Davy in 1817‖ and by Vauquelin in 1822.¶ Dr Davy proved by dissection that the yel-

* Fourcroy, x. 70.

† Neumann's Chemistry, p. 585.

‡ Ann. de Chim. et de Phys. xvii. 304. Ann. lxxi. 128.

§ Annals of Philosophy, v. 413.

‖ Phil. Trans. 1818, p. 302.

¶ Ann. de Chim. et de Phys. xxi. 440.

lowish white matter examined was not the feces but the urine of the serpent. It is voided once in from three to six weeks. Dr Davy found the urine of four species of lizards, of the alligator, the turtle, and the tortoise, similar in its consistence and constitution to that of the serpent.

VII. The excrements of the *Chamæleonis vulgaris* were examined by Dr Prout in 1820.* They consisted partly of a fine powder of a bright lemon yellow colour, and partly of lumps composed of the same powder loosely agglutinated. They consisted almost entirely of urate of ammonia and a little colouring matter. Thus they resemble very closely the excrements of the Boa constrictor. The food of the chamælonis is said to consist of the *Lumbricus terrestris* and the larvæ of the *Tenebria molitor*.

VIII. It was shown many years ago by Dr Wollaston that the *dung* of fowls consists chiefly of uric acid. The dung, or rather the urine of carnivorous birds, is very similar in its constitution to that of the Boa constrictor.

The stomach often contains gaseous matters. A quantity of gas extracted from the stomach was analyzed by Chevreul, and found composed of,

Carbonic acid,	43 volumes.
Sulphuretted hydrogen,	2
Oxygen,	4
Azotic,	31
Carburetted hydrogen,	20
	100†

* Annals of Philosophy, xv. 471.

† Leuret and Lassaigne sur la Digestion, p. 125.

CHAPTER XXV.

OF THE AIR CONTAINED IN THE SWIMMING BLADDER OF FISHES.

Many fish are furnished with a bladder filled with air, by means of which they are supposed to rise or sink in the water. When they wish to rise they are supposed to dilate their air-bladder; when they wish to sink they compress it. Whether this be the use of the air-bladder of fishes is somewhat doubtful. Most fish have a peculiar depth at which they almost always remain. Thus the flat fish constantly affect the bottom of the sea, while there are others that as constantly affect the surface. From the observations of Biot it appears, that when a fish is suddenly brought from a great depth towards the surface, the air-bladder swells so much that the fish cannot again sink; nay, it often bursts; and the air making its way into the stomach, swells it up, and forces it into the mouth or œsophagus. The air with which these bladders is filled was first examined by Dr Priestley in 1774. From his observations it appears that it varies in its nature. The roach was the fish the air-bladder of which he examined. At first he found it filled with azote, but afterwards he got a mixture of oxygen and azote. *

Fourcroy long after examined the air in the air-bladder of the carp, and found it almost pure azote: and similar results were obtained by other chemists. But by far the most complete analysis of this kind of air has been made by Biot, while in Yviza and Formentera, two islands a little to the south of Majorca and Minorca. He was employed by the French government to prolong the meridian of France to the Balearean islands, and embraced the opportunity which presented itself to examine the air in the bladders of the different species of fish caught in the neighbourhood of these islands. Next season he returned to the same islands with Mr Laroche, who repeated and confirmed his preceding experiments.†

Biot found the air in the air-bladders a mixture of azotic and oxygen gas in very variable proportions. No traces of hydrogen

* Priestley on Air, ii. 462.

† Biot's Memoirs are printed in the Mem. D'Arcueil, i. 252, and ii. 487.

gas could be detected; nor was there any sensible quantity of carbonic acid. The proportion of oxygen gas was very various, being sometimes very minute, and sometimes constituting almost the whole of the gas. The air bladders of those fish which live near the surface contained least oxygen gas, and the bladders of those which were brought up from a great depth contained the most. The following table exhibits the proportion of oxygen in 100 parts of the air in the different fish examined:

Names of the Fish.	*Prop. of Oxygen.*	*Names of the Fish.*	*Prop. of Oxygen.*
Mugil cephalus (*Linn.*)	Quant. insen.	Sciæna nigra, female,	0·27
Ditto.	Ditto.	Ditto, male,	0·25
Muræenophis helena (*Lacep.*)	Very little.	Labrus turdus (*Linn.*) female,	0·24
Sparus annularis (*Linn.*) female,	0·09	Ditto, male,	0·28
Ditto, male,	0·08	Sparus dentex (*Linn.*) female,	0·40
Sparus sargus (*Linn.*) female,	0·09	Sphyræna spet, (*Lacep.*)	0·44
Ditto, male,	0·20	Sparus argenteus,	0·50
Holocentrus marinus (*Lacep.*)	0·12	Sparus erythrinus,	Much
Labrus turdus (*Linn.*)	0·16	Holocentrus gigas,	0·69
Sparus melanurus (*Linn.*)	0·20	Gadus merluccius (*Linn.*)	0.79
Labrus turdus (*Var. Linn.*)	0·24	Trygla lyra (*Linn.*)	0·87

The depth at which the fish in the preceding table are caught increases gradually, as well as the proportion of oxygen, from the beginning to the end of the table. The last-mentioned fish, the Trygla lyra, is always caught at a very great depth. The experiments of Laroche confirm the accuracy of this curious fact. The mean result, furnished by all the fishes taken at a depth greater than 150 feet, was 0·70 of oxygen; while the mean result, furnished by the fish caught at less depths, was 0·29. This superior purity is not owing to any superior purity in the air of the water of the sea at great depths. The air obtained from sea water, brought up from a great depth, yielded 0·265 of oxygen, while that from water taken at the surface was purer.

It is very remarkable that the air in the bladder of fishes, taken near the surface, should be almost pure azote. But this holds also with respect to fresh water fish. Thus Biot found the air in the air-bladder of a carp to contain 0·03 of oxygen, while that of a tench contained 0·16; and Geoffroy and Vauquelin found the air in the air-bladder of pikes, loaches, and perches, to contain 0·05 of oxygen. Humboldt likewise found very little oxygen in the air-bladder of the Gymnotus electricus.

PART III.

OF MORBID CONCRETIONS.

Solid bodies are apt to be deposited in various cavities, both of the human body and of the inferior animals. These occasion uneasiness frequently terminating in disease and death. These concretions, so far as they have been investigated by chemists, may be arranged under the six following heads:—

1. Urinary calculi.
2. Gouty concretions.
3. Salivary concretions.
4. Biliary concretions.
5. Ossifications.
6. Intestinal concretions.

These will be treated of successively in the six following chapters.

CHAPTER I.

OF URINARY CALCULI.

It is well known that concretions not unfrequently form in the kidneys or bladder, and occasion one of the most dismal diseases to which the human species is liable.

These concretions were distinguished by the name of *calculi*, from a supposition that they are of a stony nature. Their existence must have been known from the very commencement of medical science. The mode of extracting them by an operation was known to the ancients, and is described by Celsus. Chemistry had no sooner made its way into medicine than it began to exercise its ingenuity on the urinary calculi; and various theories of their nature and origin were given. According to Paracelsus, who distinguished them by the name of *duelech*, they were intermediate between *tartar* and stone,* or were composed of a mucilaginous tartar that floated in the blood-vessels. In his fourth tract, *De Elemento Aquæ*, cap. 8, he gives characters of *duelech;* but they differ so much from those of urinary calculi that it is not worth while to transcribe them. The school-

* De Morbis Tartareis, cap. 11.

men considered calculi as a peculiar *mucilage* concocted and petrified by the heat of the body. These opinions were ably refuted by Van Helmont in his treatise *De Lithiasi,* which contains the first attempt towards an analysis of urine and urinary calculi; and, considering the period when it was written, is certainly possessed of uncommon merit. He demonstrates that the materials of calculi exist in the urine. He considers them as composed of a volatile earthy matter, and the saline spirit of urine, which coagulate instantaneously when they come in contact; but which are prevented from combining in healthy people, by what he calls *scoria,* which saturates the salt of urine.*

Boyle found calculi soluble in nitric, but insoluble in sulphuric acid and muriatic acid and vinegar.† Thus showing the species upon which his experiments had beeen made. Slave attempted a chemical analysis of them.‡ Hales extracted from them a prodigious quantity of air. He gave them the name of *animal tartar;* pointed out several circumstances in which they resemble common tartar, and made many experiments to find a solvent for them.§ Drs Whytt and Alston pointed out alkalies, particularly lime, as the best solvents of calculi. The first attempt at a description of human urinary calculi that I have met with was by Dr Lewis in his notes on Neumann's Chemistry, published in 1759.||

Such was the state of the chemical knowledge of urinary calculi when Scheele published a set of experiments upon a collection of them, which he had made; in the Memoirs of the Stockholm Academy for 1776.¶ All that he examined were of the same nature. Scheele showed that they consisted of an acid, to which the name of *uric acid* was given. He considered calculi as oily salts composed of a mucilaginous matter with uric acid in excess. To Scheele's paper an appendix was added by Bergman. He also had been engaged in examining urinary calculi. Some he found to agree in their nature with those of Scheele, while others consisted chiefly of phosphate of lime.

Scarcely any addition was made to the discoveries of Scheele

* *De Lithiasi,* p. 21. Constituting an appendix to Van Helmont's Opera.
† Shaw's Boyle, iii. 557. ‡ Phil. Trans. xvi. 140.
§ Veget. Statics, ii. 189.
|| Lewis's Neumann's Chemistry, p. 532.
¶ Kongl. Vetenskiaps Acad. Hand. 1776, p. 327.

and Bergman till Dr Wollaston published his important paper on urinary and gouty concretions in 1797. Mr Lane, indeed, examined the action of heat on various calculi, and the quantity of each dissolved in 48 hours in caustic potash.* About the year 1797, Brugnatelli published some observations on urinary calculi.† Those which he examined he found partly soluble in water, and he says that the portion dissolved was biphosphate of lime. The portion not soluble in water was uric acid, and he says that, when treated with nitric acid, a great part of it was converted into oxalic acid.

Dr Wollaston, in his paper published in the Philosophical Transactions for 1797 (p. 386), describes four new species of calculi, which had been observed indeed before, but their chemical constitution was unknown till it was determined by Wollaston. These were, 1. *Fusible calculus.* It had been observed by Smithson Tennant, that when this calculus was exposed to the action of the blowpipe, instead of being consumed like the uric acid calculus of Scheele, it left a considerable residue, which fused into an opaque white glass. Wollaston found that these calculi contained brilliant crystals of ammonia-phosphate of magnesia, which were usually mixed with phosphate of lime and some uric acid. 2. *Mulberry calculus.* This name had been given by surgeons to a dark-coloured calculus with an uneven surface, bearing some resemblance to a mulberry. Hence the name. Dr Wollaston found that it consisted essentially of oxalic acid combined with lime. The smooth calculus known by the name of *hemp-seed* calculus, Wollaston found also to be chiefly oxalate of lime; but to contain phosphate of lime and some uric acid. From the late investigations of Wöhler and Liebig, it seems to be very probable that the mulberry calculus is in reality a compound of oxaluric acid and lime. 3. *Bone earth calculus.* This calculus has a brown colour, is smooth, and composed of concentric laminæ, easily separated from each other. Before the blowpipe it is at first charred; then becomes perfectly white, and urged by the utmost heat of the blowpipe it fuses. It consists essentially of phosphate of lime; and differs from bone earth by containing no carbonate of lime. 4. *Calculi from the prostate gland.* These are small calculi having the colour and transparency of

* Phil. Trans. 1791, p. 223. † Ann. de Chim. xxviii. 52.

amber. They consist of phosphate of lime tinged with the secretion of the prostate gland.

About the commencement of the present century Fourcroy and Vauquelin announced their intention of making a rigid analysis of all the calculi which they could procure, and invited medical men to send them specimens. In this manner they obtained and examined about 600 different calculi. They found the same substances which Wollaston had described, and likewise urate of ammonia, and in two calculi a quantity of silica. It is remarkable that, though Dr Wollaston's experiments had been published three years before, and in the Philosophical Transactions, a copy of which is regularly transmitted to the Academy of Sciences, of which Fourcroy was a member ; yet Fourcroy, who drew up the account of the experiments, takes no notice whatever of the previous labours of Wollaston, who had anticipated almost all the discoveries which they made respecting the constitution of calculi.*

In the year 1808,† Mr Brande examined the calculi in the Hunterian Museum, at that time in the possession of Sir Everard Home, but now the property of the University of Glasgow. He informs us that he examined 150 calculi, and found their constitution as follows:

16	were composed of uric acid.
46	of uric acid with a small portion of phosphates.
66	of phosphates with a little uric acid.
12	composed of phosphates entirely.
5	of uric acid with the phosphates and nuclei of oxalate of lime.
6	of oxalate of lime chiefly.
150	

Mr Brande endeavours to prove that the urate of ammonia found by Fourcroy and Vauquelin was only a mixture of uric acid and sal-ammoniac. It is remarkable that, as far as my observations go, and I have examined the Hunterian collection of calculi with considerable attention, it contains no calculus consisting of urate of ammonia. But in the collection of the late

* Fourcroy's papers appeared in various volumes of the *Annales de Chimie*, and in his *Systeme des connoissances Chimiques*.

† Phil. Trans. 1808, p. 223.

Dr George Monteath of Glasgow, which I examined particularly, there were no fewer than six calculi composed either of urate of ammonia, or of a mixture of uric acid and urate of ammonia. These calculi were all extracted from young children. They were small; but had been a source of such uneasiness while in the bladder, that the noise produced by opening or shutting a door was apt to throw the child into convulsions.

In 1810,* Dr Wollaston discovered a new calculus, to which he gave the name of cystic oxide. It was subjected to an ultimate analysis by Dr Prout.

Proust stated that in some urinary calculi which he examined, he found a quantity of carbonate of lime. This statement was at first called in question, because Fourcroy and Vauquelin found no such substance in the numerous calculi which they examined. But it has been confirmed by subsequent researches. In Dr George Monteath's collection, there was a calculus extracted from a Highlander of 26 years of age. It was white, but not friable; nor did it stain the fingers. It was composed of about one part of carbonate of lime and two parts of phosphate of lime; and contained, besides, crystals of ammonia-phosphate of magnesia.

In 1817, Dr Marcet published his *Essay on the Chemical History and Medical Treatment of Calculous Disorders.* In this work he gave an account of two new species of urinary calculi. The first of these he called from its colour *xanthic oxide.*† It was subjected to a chemical analysis by Wöhler and Liebig, who showed that it differed from uric acid by containing two atoms less of oxygen. The second calculus was composed entirely of animal matter, possessing the characters of fibrin. Marcet gave it the name of *fibrinous* calculus.‡

Berzelius informs us that Lindbergson analyzed a urinary calculus composed of urate of soda and carbonate of magnesia.§ It was therefore analogous to the gouty concretions analyzed by Dr Wollaston.

Urinary calculi are most commonly ellipsoidal or egg-shaped. They vary very much in size; sometimes being not larger than the head of a pin, and sometimes almost as large as a moderate sized fist. I have seen one which was extracted after death from

* Phil. Trans. 1810, p. 223. † Essay, p. 95. ‡ Ibid. p. 101.
§ Traité de Chimie, vii. 413.

an alderman of Dublin, and which almost completely filled the bladder, that weighed several pounds.* The surface is sometimes smooth and polished and sometimes rough, being covered with numerous tubercles. The colour is sometimes brown, sometimes white, and in the mulberry calculi almost black. Sometimes they are studded with crystals of ammonia-phosphate of magnesia. The specific gravity, according to Fourcroy, varies from 1·213 to 1·976.†

In general, when a calculus is sawn in two, we perceive that it is composed of a number of concentric layers, covering a nucleus. These layers (together with the nucleus) are sometimes all composed of the same matter; but more frequently the nucleus consists of a substance quite different from the concentric layers that cover it. Uric acid and oxalurate of lime are very common nuclei. The concentric layers are sometimes composed of the same materials; but frequently also of different materials. Thus they may consist of uric acid or phosphate of lime, or triple phosphate, or of two or more of these intermixed.

The urinary calculi hitherto observed may be conveniently arranged under the following genera:

1. *Uric acid calculi.*—Their most common colour is brown, differing somewhat in the depth of shade. But this is not always the case, for I have in my possession several small uric acid calculi passed per urethram, almost as white as chalk. The surface is sometimes smooth and polished, but not unfrequently tubercular. The specific gravity varies from 1·5 to 1·786. But sometimes it is as low as 1·276. It is usually composed of concentric laminæ, differing in thickness and exactly resembling each other. Each lamina is composed of fibres, (or small crystals,) so placed as to be perpendicular to the central point of the calculus. Judging from the collections of calculi which I have seen, (amounting in all to not fewer than 1000,) this is by far the most common of all the urinary calculi.

Uric acid calculi are very sparingly soluble in water; requiring at least ten thousand times their weight of that liquid. But they dissolve readily in caustic potash or soda ley, especially

* Sir James Earl describes a stone taken out of the bladder after death that must have been larger than this. It filled the bladder, and weighed 3 lbs. 4 oz. troy. It consisted of a congeries of calculi united together. It was composed chiefly of triple phosphate. See Phil. Trans. 1809, p. 303.

† Systeme, x. 213.

when assisted by heat, and the uric acid is precipitated from the solution by all acids, even by the acetic.

2. *Urate of ammonia calculi.*—These calculi, so far as I have seen them, are all small. They are whitish or clay-coloured, and composed of concentric coats. They have usually a uric acid neucleus, and probably contain uric acid mixed with the urate of ammonia. According to Fourcroy and Vauquelin, their specific gravity varies from 1·228 to 1·720. They are obviously rare; as there is not a single specimen in the Hunterian collection, consisting of several hundred calculi. It was this circumstance, probably, that led Mr Brande to conclude that no calculi composed of urate of ammonia exist.

Laugier, in 1824, analyzed a calculus taken out of the bladder after death. It was brown, soft, and friable, and could only be extracted in fragments. Laugier found its constituents to be,

Uric acid,	10
Urate of ammonia,	40
Phosphate of ammonia,	5
Oxalate of lime,	15
Animal matter,	20
Moisture and loss,	10
	100 *

Boutron-Charlard also found urate of ammonia in a urinary calculus. †

3. *Phosphate of lime calculi.*—This calculus, first determined and described by Dr Wollaston, is much less frequent than uric acid calculi. The colour is usually a pale brown, and the surface is quite smooth and polished. It is composed of concentric laminæ, in general adhering so slightly to each other as to separate with ease into concentric crusts. The surface of each of which, like that of the outermost, is quite smooth. The laminæ are sometimes striated in a direction perpendicular to the surface.

When this calculus is ignited it becomes black, in consequence of the charring of the animal matter which it contains, but it soon burns white, and remains unaltered before the blowpipe, unless a very high temperature be applied, when it may be fused. It is more easily fusible than the earth of bones, because it contains little or no carbonate of lime. When in powder it dissolves readily in nitric or muriatic acid.

* Jour. de Pharmacie, x. 258 † Ibid. xxii. 556.

This calculus is rare, only about a dozen of such occur in the Hunterian collection.

4. *Ammonia-phosphate of magnesia calculi.*—Strictly speaking, this does not constitute a peculiar species, as the double phosphate always contains a considerable mixture of phosphate of lime ; at least, if any exist composed of the double phosphate of magnesia and ammonia alone, I have never happened to see them. These calculi are yellowish-white, and have usually a tuberculated surface. It is not uncommon to meet with calculi containing crystals of the double phosphate. When these crystals are exposed to the action of the blowpipe ammonia is disengaged, and biphosphate of magnesia remains, which undergoes an imperfect fusion.

5. *Fusible calculi.*—These calculi are composed of a mixture of double phosphate and phosphate of lime. They are more abundant than any other species, except the uric acid calculi. They are whiter and more friable than any other species. Sometimes they resemble a mass of chalk, and leave a white dust upon the fingers. They easily separate into laminæ, the interstices of which are often studded with crystals of the double phosphate. But this laminated structure is not always observable. They often acquire a very large size, sometimes nearly filling the whole cavity of the bladder. When these calculi are urged by the blowpipe they readily melt into a vitreous globule; in consequence of the mutual action of the biphosphate of magnesia and phosphate of lime on each other.

When this calculus is pulverized and treated with acetic acid, the ammonia-phosphate of magnesia is dissolved, and the phosphate of lime remains nearly pure; muriatic acid being poured upon this residue, dissolves the phosphate of lime, and usually leaves a quantity of uric acid, which not uncommonly constitutes the nucleus of the calculus. The proportions of these constituents, and with them the appearance of the calculus, varies very much. When the calculus is large the outermost crust not unfrequently contains a greater proportion of ammonia-phosphate of magnesia than the internal parts. It is not uncommon to find a nucleus of uric acid or oxalate of lime covered by a crust of phosphate of lime, and that again by a crust of fusible calculus.

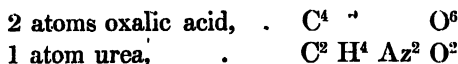
6. *Carbonate of lime calculi.*—These calculi are common in the inferior animals, but very rare in man. It has been already stated that human calculi containing carbonate of lime were first

pointed out by Proust. I have only met with one such calculus. It was in the collection of the late Dr George Monteath, and had been extracted from Hugh M'Lean from Cowal in Argyleshire, a young man of twenty-six years of age. The calculus was not large. It was white, but not friable, nor did it stain the fingers. Its nucleus was crystalline, and composed almost entirely of ammonia-phosphate of magnesia. The calculus itself, if we do not reckon the animal matter, which was but small, consisted of one part carbonate and two parts phosphate of lime. Bergman also analyzed a calculus consisting chiefly of carbonate of lime. It was of a dirty-white colour, or in some places yellow. It readily separated into small concretions about the size of a pinhead, which had a crystalline structure. They were soft. This calculus consisted chiefly of carbonate of lime with an animal matter, which cemented the particles together. It contained no uric acid, nor phosphoric acid, nor oxalic acid; nor indeed could any other acid be detected except carbonic.* Marchand found two carbonate of lime calculi in the Berlin Museum. These he subjected to analysis, and found them composed of

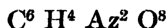
Carbonate of lime,	.	96·50
Phosphate of lime,	.	2·05
Oxide of iron,	.	0·05
Animal matter,	.	1·40
		100·00†

7. *Mulberry calculi.*—This calculus, which is not unfrequent, is usually hard, of a dark dirty-greenish or brownish colour, and with a tuberculated surface, in consequence of which it got the name of mulberry calculus. Dr Wollaston first subjected this kind of calculus to examination, and extracted from it oxalic acid and lime. Hence he concluded that it consisted of oxalate of lime mixed with some uric acid and phosphate of lime. But there can scarcely be a doubt that the true constituent is oxalurate of lime,

Wöhler and Liebig have shown that oxaluric acid is a compound of



2 atoms oxalic acid, . $C^4 \quad O^6$
1 atom urea, . $C^2 H^4 Az^2 O^2$



$C^6 H^4 Az^2 O^8$

* Poggendorf's Annalen, xix. 556. † Ann. der Pharm. xxxii. 323.

When the solution of this acid is concentrated it deposites crystals of oxalate of urea, and then of pure oxalic acid. Hence at the time that Dr Wollaston made his experiments (1797), it was impossible for him to have drawn any other conclusion than that the acid constituent of the calculus was oxalic.

Calculi occur, which from their appearance have been called *hemp-seed calculi.* They are always small, pale-coloured, and remarkably smooth on the surface. Dr Wollaston examined them, and found them also to consist of oxalate of lime. It would be an object of some consequence to ascertain by a chemical analysis whether the acid which they contain be *oxalic* or *oxaluric*. These hemp-seed calculi must be very rare. I have only seen one specimen in all the numerous collections of calculi which I have examined.

Dr Marcet met with three different specimens of mulberry calculi, passed per urethram by three different persons, and having each a distinct crystalline texture. The shape of the crystal was a very flat octahedron.*

6. *Urate of soda calculi.*—Dr Wollaston first showed that the *chalk stones* which form in the joints of gouty patients consist chiefly of urate of soda. Berzelius informs us that M. Lindbergson analyzed a urinary calculus which he found composed of urate of soda and carbonate of magnesia. I met with a parcel of very small calculi in the collection of Dr George Monteath, which were coated on the surface with urate of soda. They were obtained from a man of 60 years of age, who laboured under a diseased prostate gland. These calculi were 40 in number, about the size of a pea, some cylindrical and others approaching to the cubic shape. Within they were yellow, but the external surface was white. The yellow portion was uric acid. From the white surface I extracted uric acid and soda.

There was in the same collection another calculus extracted after death. It consisted of a mulberry nucleus, covered by a pretty thick coat of uric acid. The surface was white, and had exactly the appearance of the surface of the small calculi just mentioned. Hence I considered it probable that it consisted also of urate of soda, but I had not an opportunity of examining it.

9. *Cystic oxide calculi.*—This rare calculus, the substance constituting which has already been described under the name of

* Marcet's Essay, p. 78.

cystin,* was first described and examined by Dr Wollaston.† Calculi composed of it have a pale yellow colour, are translucent, and appear irregularly crystallized. It was analyzed by Dr Prout, and found composed of C^{12} H^{12} Az^{2} O^{16}. It is, therefore, probably related to oxaluric acid. Being, in fact, two atoms of oxaluric acid + eight atoms water + one atom azote.

Stromeyer found cystic oxide in the gravel passed by a patient. The urine of this patient contained a good deal of cystic oxide, but hardly any uric acid; and the urea was not in its natural state.‡

10. *Xanthic oxide calculi.*—Only two specimens of this very rare calculus have been hitherto observed. Dr Marcet first described it from a specimen from Drs Babbington and Wöhler, and Liebig analyzed it from a much larger calculus extracted from a patient by M. Langenbeck, and still preserved in Lagenbeck's collection. They found its constituents C^{10} H^{4} Az^{4} O^{6}. Now uric acid is C^{10} H^{4} Az^{4} O^{8}. It differs, therefore, from the xanthic oxide of Marcet, by containing two atoms more oxygen. Hence the reason why Wöhler and Liebig have given it the name of *uric oxide*. It is even much rarer than cystic oxide; since only two calculi composed of xanthic oxide have been hitherto discovered.

11. *Fibrinous calculi.*—Only a single calculus of this kind has been hitherto met with. It was about the size of a pea, and was given by Sir Astley Cooper to Dr Marcet.

It had a yellowish-brown colour, somewhat resembling bees'-wax. Its hardness was also nearly that of bees'-wax. Its surface was uneven, but not rough to the touch; its texture rather fibrous, and the fibres apparently radiating from the centre. It was somewhat elastic. It burnt with flame, emitting an animal smell, which did not resemble that of uric acid, cystic, or uric oxide calculus. It was insoluble in water and in muriatic acid, but it formed a soapy solution with caustic potash, from which it was precipitated by muriatic acid. Nitric acid dissolved it, though not very readily, and the solution when evaporated to dryness did not leave a red or yellow stain. When boiled in very dilute nitric acid, it swelled to a great size, and was at last dissolved. The solu-

* See page 105. † Phil. Trans. 1810, p. 223.

‡ Ann. de Chim. et de Phys. xxvii. 221.

tion was precipitated yellow by prussiate of potash.* The gentleman who passed this calculus was from fifty to fifty-five years of age. He had been labouring under symptoms of urinary calculi for two years, recurring in the form of severe paroxysms. He never had any pain in the kidneys or ureters, but during the paroxysms there was great pain about the neck of the bladder, with bloody urine, and frequent difficulty in passing it. Under these circumstances, he passed three fibrinous calculi at three different times.†

12. *Ferruginous calculi.*—Only a single calculus of this description has been met with. It had been formed in the kidney, and was passed by a lady in Bogota, and subjected to analysis by M. Boussingault. It weighed 17 grains, and was about the size of a hazelnut. Its form was irregular, though in some parts it had a lamellated structure. Its colour was not uniform, being in some parts ochre-yellow, in others deep-brown. It had great resemblance to bog-iron ore, and had a specific gravity of 2·886. Its constituents, as determined by the analysis of Boussingault, were,

Peroxide of iron,	38·81
Alumina,	23·00
Silica,	17·25
Lime,	8·02
Water,	10·89
	98·17‡

If no deception was practised, this must be allowed to be a most extraordinary concretion from the bladder of a woman.

Such are the different species of human urinary calculi hitherto observed and examined. It is hardly necessary to remark, that the species of more frequent occurrence are often mixed together in the same calculus usually in concentric coats. The most common nucleus is uric acid and oxalurate of lime. When the stone is large, and has remained long in the bladder, the outermost coats in general consist of fusible calculus; for it is a remarkable fact, and well deserving the attention of medical men, that whenever the bladder becomes diseased from irritation, the quantity of phosphate of lime and ammonia-phosphate of magnesia in

* Marcet's Essay, p. 101. † Ibid. p 103.
‡ Jour. de Pharm. xi. 153.

the urine is increased, or at least its tendency to precipitate is very much augmented. This is partly, no doubt, owing to the evolution of ammonia in the urine, which almost always takes place when the inner coat of the bladder is diseased. Calculi composed of phosphate of lime are rare, and in general they contain no other ingredient than phosphate of lime cemented by animal matter, and disposed in concentric coats. In some rare cases, the external coat, or at least part of it, is uric acid; but an external coat of fusible calculus or ammonia-phosphate of magnesia is rare. This would indicate that the urine in which phosphate of lime calculi are deposited is not ammoniacal.

There can be little doubt that the nucleus of almost all the calculi is formed in the kidney: and what is called a fit of the gravel is the pain felt while that nucleus is passing from the kidney through the ureter to the bladder. We must except those cases in which any solid substance makes its way into the bladder; because a urinary calculus almost always is deposited upon this solid matter. Thus in the Hunterian collection there is a large fusible calculus, which has for its nucleus a piece of leaden sound. I have seen a calculus formed upon a pin, which must have been thrust into the bladder, (probably of a female,) through the urethra. Dr Marcet gives an instance of a musket-ball lodged in the bladder, round which as a nucleus a urinary calculus had concreted.

As most of the constituents of urinary calculi exist in the urine, there is no great difficulty in conceiving how they may originate, either in the kidney or bladder.

Uric acid being a constant constituent of urine, and being very little soluble, we can easily see how it may be deposited whenever the quantity of free acid, which urine contains, happens to be augmented. If uric acid exists in urine (as Dr Prout conjectures) in the state of *urate of ammonia*, that salt would be deposited whenever it exists in greater than its usual quantity in ammoniacal urine. It is very curious that this state of the urine should be confined to children, and that the deposition of such calculi produces so great a degree of irritation.

Phosphate of lime exists in urine though in small quantity. It is doubtless held in solution by the acid which healthy urine contains in excess. Hence phosphate of lime can only be deposited when the urine becomes alkaline by the evolution of am-

monia. Now it is curious, that whenever the urine becomes ammoniacal, the quantity of phosphate of lime which it contains is very much increased. We might, therefore, expect depositions of phosphate of lime in alkaline urine. And I believe that this happens in almost every case. But the deposit is usually in powder, and it is evacuated along with the urine, unless a nucleus already exist to which it can attach itself, or unless a quantity of thick mucus sufficient to form with the powder a solid concretion happens to be present.

Phosphate of magnesia exists in urine in very minute proportion, and doubtless in the state of *biphosphate*. When the urine becomes ammoniacal, this biphosphate is saturated with ammonia, and converted into ammonia-phosphate of magnesia, which, being quite insoluble, is of course precipitated along with the phosphate of lime. It is probable that, when the urine becomes ammoniacal, the quantity of biphosphate of magnesia, which it naturally contains, is greatly augmented. Hence the reason of the great quantity of ammonia-phosphate of magnesia found in the fusible calculi.

It has been shown that urine in certain cases contains a considerable quantity of *carbonic acid*. If we were to admit that when this is the case, the urine (in certain cases at least) may contain bicarbonate of lime, it would explain the very rare formation of calculi containing carbonate of lime as one of their constituents.

It has been shown by Wöhler and Liebig that when uric acid is treated with nitric acid, it is (under certain circumstances), converted into parabanic acid, and that, when parabanic acid is united to a base, it is converted into oxaluric acid. Now Dr Prout informs us that he has met with nitric acid in certain cases in human urine. We can, therefore, in some measure, account for the formation of mulberry calculi consisting of oxalurate of lime. The formation requires the existence of nitric acid in urine. It is true, indeed, that Wöhler and Liebig found it necessary to employ nitric acid of a given density, to apply heat, and to dissolve in it solid uric acid, in order to obtain parabanic acid. But in the living body the process is much more slow. Nor can there be any reason to doubt that nitric acid, even in the dilute state in which it may exist in urine, may be capable, slowly and silently, to produce the same change on uric acid in the living body, that concentrated nitric acid, assisted by heat, produces upon solid uric acid.

As urine contains both uric acid and soda, we have no reason to be surprised at occasionally finding *urate of soda* in urinary calculi. Whenever the urine is rendered alkaline by a long continued use of carbonate of soda, one would naturally expect that the urate of ammonia would be converted into urate of soda, which being insoluble or nearly so, would be precipitated in crystalline grains or in powder, and this powder, cemented by the mucus of the inside of the bladder, might give origin to a nucleus of urate of soda. The great rarity of such calculi shows how seldom the urine is rendered alkaline by an excess of soda.

Cystic oxide calculi are very rare. As this substance, so far as we know, does not exist in urine, we cannot so readily account for its appearing in the urinary organs. We might indeed easily start various hypotheses to connect cystic oxide with uric acid, oxaluric acid, and some other substances which either exist ready formed in the urine, or make their appearance in certain cases. But we refrain, because such hypotheses have very little tendency to improve our knowledge.

Uric oxide, differing from uric acid simply by containing two atoms less oxygen, we have only to conceive the action of some deoxygenizing principle upon uric acid in the urine, in order to account for the appearance of these calculi. Carbon, for example, in some state or other, might be conceived to deprive uric acid of two atoms oxygen, and to be converted into carbonic acid, while it left the uric acid converted into uric oxide.

Fibrinous calculi seem always to be formed in the bladder. We cannot at present account for their origin, though it may be connected with the presence of albumen in urine. For it has been shown in a former part of this work that albumen and fibrin are mere varieties of the same animal principle.

Urinary calculi from the inferior animals.—These calculi have hitherto been imperfectly examined. Indeed, if we except those animals which have been domesticated, few opportunities occur for examining the calculi which may be formed in the urinary organs of the inferior animals.

1. *The Horse.*—Dr Pearson analyzed several calculi from the horse. He found them to consist of phosphate of lime, phosphate of ammonia, and animal matter.* But a calculus from a

* Phil. Trans. 1798, p. 15.

horse, which was given him by Dr Baillie, and which had been found in the kidney, had a different composition. It was of a blackish colour, very brittle and hard, and had no smell or taste. It was heavier than human urinary calculi. It proved on analysis to consist of carbonate of lime cemented together by animal matter.*

Mr Brande analyzed three urinary calculi from the horse; the first from the kidney, and the other two from the bladder. He found their composition as follows:

	1.	2.	3.
Phosphate of lime,	76	45	60
Carbonate of lime,	22	10	40
Ammonia-phosphate of magnesia,	...	28	...
Animal matter,	...	15	...
	98	98	100†

Wurzer and John had found carbonate of magnesia in small quantity in the calculi from the horse, and this was confirmed in 1823 by the experiments of Lassaigne.‡

2. *The Ox.*—Fourcroy and Vauquelin seem to have been among the first chemists who examined the urinary calculi of the ox. They found those which they subjected to analysis composed chiefly of carbonate of lime. This constitution was confirmed by Brande, who analyzed several calculi from the bladder of the ox, and found them composed of carbonate of lime and animal matter.§ M. Lasaigne examined several in 1823, and found that the carbonate of lime was mixed with a little carbonate of magnesia.‖

3. *The Sheep.*—Mr Brande analyzed a urinary calculus of a sheep, and found it composed of,

Phosphate of lime,	72
Carbonate of lime,	20
Animal matter,	8
	100¶

In the year 1830, M. Lassaigne examined a siliceous calculus found in the urethra of a male lamb of the Merino breed. It was white, with a slight shade of red, very friable, and had a cy-

* Phil. Trans. 1798, p. 15.
† Ibid. 1808, p. 233.
‡ Ann. de Chim. et de Phys. xxii. 440.
§ Phil. Mag. xxxii. p. 178.
‖ Ann. de Chim. et de Phys. xxii. 440.
¶ Phil. Trans. 1808, p. 235.

lindrical shape, tapering towards the extremities. It was composed of concentric coats adhering very slightly to each other. It was composed of silica mixed with a small quantity of peroxide of iron and some animal matter.*

4. *The Hog.*—Fourcroy found the calculus from a hog, examined by him and Vauquelin, to consist almost entirely of carbonate of lime. And a urinary calculus from a hog analyzed by Mr Brande, contained 90 per cent. of carbonate of lime, and the rest was animal matter.† In the year 1811, I analyzed a calculus from the urethra of a hog, which I got from Mr Colville, surgeon in Ayton, Berwickshire. It was nearly spherical, weighed 44·2 grains, and had a specific gravity of 1·595. It was white, had a silky lustre, and was composed of a congeries of very small needles. It consisted entirely of phosphate of lime and animal matter.‡ In 1825, a calculus from the bladder of a hog was analyzed by M. Caventou, who found its constituents to be,

Ammonia-phosphate of magnesia,	99·5
Animal matter, . .	0·4
	99·9§

In the Hunterian collection of calculi in the Glasgow University museum there is a small phial containing a number of dark-coloured *pearls*, labelled as extracted from the bladder of a hog. They consist of alternate layers of carbonate of lime and animal matter.

From these facts it appears that the urinary calculi of hogs, so far as they have been examined, consist sometimes of carbonate of lime, sometimes of phosphate of lime, and sometimes of ammonia-phosphate of magnesia.

5. *The Dog.*—Fourcroy and Vauquelin examined several calculi from the bladder of the dog, and found them similar to the human mulberry calculi.‖ Mr Brande in 1808 analyzed a large calculus from the bladder of a dog twenty years of age. It weighed sixteen ounces, was extremely hard, and of a gray colour. When cut through it exhibited a nucleus about the size of a hazel-nut, partly made up of concentric layers of phosphate

* Ann. de Chim. et de Phys. xliv. p. 420. † Phil. Trans. 1808, p. 236.
‡ Annals of Philosophy, ii. p. 59. § Jour. de Pharmacie, xi. p. 465.
‖ Ann. de Mus. d'Hist. Nat. iv. p. 338.

of lime, and partly of crystals of ammonia-phosphate of magnesia. The part of the stone investing this nucleus was composed of,

Phosphate of lime,	64
Ammonia-phosphate of magnesia,	30
Animal matter,	6
	100

Gray-coloured sand from a dog's bladder was analyzed by the same chemist, and found composed of,

Carbonate of lime	20
Phosphate of lime,	80
	100*

In 1825, M. Lassaigne examined a calculus from the bladder of a dog, deposited in the collection of the Veterinary School at Alfort. It was yellowish, semitransparent, and possessed all the characters of cystic oxide mixed with a little phosphate of lime and oxalate of lime. Its constituents by analysis were,

Cystic oxide,	97·5
Phosphate and oxalate of lime,	2·5
	100†

A good many years ago I received from Montreal a small parcel containing about a dozen of *pearls*, which had been extracted from the bladder of a dog. The colour was rather too dark, and the surface too cloudy to permit these pearls to be used for ornamental purposes; but they were much more beautiful than the pearls in the Hunterian collection from the bladder of a hog.

In 1818, Lassaigne had analyzed a calculus from the bladder of a dog. It was yellowish, of an irregular shape, and was about the size of a hazel-nut. It was composed of urate of ammonia mixed with a little phosphate of lime.‡

From these different analyses there is reason to suspect that the calculi of the dog are as much diversified in their chemical constitution as those of man.

6. *The Cat.*—The only chemist who has examined the calculi from the bladder of the cat is Vauquelin, according to whom their constitution is similar to that of human calculi.§

* Phil. Trans. 1808, p. 235. † Ann. de Chim. et de Phys. xxiii. p. 328.
‡ Ann. de Chim. et de Phys. ix. p. 324. § Ann. de Chim. lxxxiii. p. 146.

7. *The Rabbit.*—Dr Pearson was the first person who examined the urinary calculus of a rabbit. It had a dark-brown colour, was spherical, and about the size of a small nutmeg. It was hard, brittle, and had a specific gravity of 2. It was composed of concentric laminæ. He found it composed of carbonate of lime and animal matter.* Mr Brande analyzed another urinary calculus of the rabbit in 1808. It was of a dark gray colour, weighed four drachms, and seemed formed of a congeries of smaller calculi. Its constituents were,

Phosphate of lime, . .	39
Carbonate of lime, . .	42
Animal matter, . . .	19
	100†

8. *The Rat.*—Fourcroy and Vauquelin seem to be the first chemists who examined the urinary calculi of the rat. The specimens which came under their observation were composed, they inform us, of oxalate of lime.‡ I am not aware of any later analysis of these concretions.

9. *The Rhinoceros.*—No calculi from the bladder of this animal have been examined. But Mr Brande informs us that the urine of the rhinoceros when voided is very turbid; and that when allowed to remain at rest it deposits a very large proportion of sediment, which consists of carbonate of lime with small portions of phosphate of lime and animal matter.§ It therefore resembles the urine of the horse. From this there is reason to conclude that the urinary calculi of the rhinoceros must in their constitution resemble those of the horse.

CHAPTER II.

GOUTY CONCRETIONS.

CONCRETIONS occasionally make their appearance in the joints of those persons who have long laboured under gout. From the colour and softness of these concretions they were distinguished

* Phil. Trans. 1798, p. 15. † Ibid. 1808, p. 236.
‡ Ann. de Mus. d'Hist. Nat. iv. p. 338. § Phil. Trans. 1808, p. 234.

by the name of *chalk stones.* They are usually small, though it is stated by Severinus that they have been observed as large as an egg. It had long been the opinion of physicians, founded upon an alternation observed between the paroxysms of gout and the passage of gravel in the urine, that these concretions were similar to urinary calculi. Hence, after the discovery of uric acid by Scheele, it was usual to consider the gouty chalk stones as concretions of that acid. They were first subjected to a chemical analysis by Dr Wollaston in 1797, who found them composed of uric acid and soda.

Gouty concretions are soft and friable. Cold water has little effect on them, but boiling water dissolves a small portion. If an acid be added to this solution, small crystals of uric acid are gradually deposited on the sides of the vessel containing the solution. They are completely soluble in potash when the action of the alkaline solution is assisted by heat.

When they are treated with dilute sulphuric acid or with muriatic acid, the soda is separated, but the uric acid remains, and may be separated by the filtre. When the liquid is evaporated it yields crystals of sulphate of soda or of common salt, according to the nature of the acid employed. The residuum possesses all the characters of uric acid.

When uric acid, soda, and a little warm water are triturated together, a mass is formed, which, after the surplus of soda is washed off, possesses the chemical properties of gouty concretions.*

CHAPTER III.

SALIVARY CONCRETIONS.

Small concretions occasionally occur in the salivary glands, especially the parotid and sublingual. These calculi were first subjected to a chemical examination by Dr Wollaston, who found them composed of phosphate of lime, associated with a membranous substance. Fourcroy's analysis gave the same result. A small salivary concretion which I examined was composed of phosphate of lime united to a membranous substance,

* Wollaston, Phil. Trans. 1797, p. 386.

which retained the shape of the concretion after the solution of the phosphate of lime. In a salivary concretion weighing one and a-half grain, examined by Dr Bostock, the whole consisted of phosphate of lime, except a few films of matter, which was considered as coagulated albumen.* In 1827, a salivary concretion was subjected to a chemical analysis by M. Lecanu.† It weighed 7 grains, had an ovoid shape, was slightly wrinkled on the surface, and was composed of two distinct concentric laminæ, the innermost of which was hard, compact, and gray, while the outermost was friable and perfectly white. Its constituents were,

Phosphate of lime, .	75
Carbonate of lime, .	20
Animal matter and loss, .	5
	100

Laugier had previously found some carbonate of magnesia in a salivary concretion. But no traces of that earth could be found in the concretion analyzed by Lecanu.

2. M. Lassaigne, in 1821, examined a salivary concretion from a horse.‡ It was an elongated ellipsoid; and was composed of concentric coats, all seemingly of the same nature. Its constituents were found to be,

Carbonate of lime, .	84
Phosphate of lime, .	3
Animal matter, .	9
Water, . . .	3
	99

In 1828, M. Henry, Junior, analyzed a salivary concretion taken from the anterior jaw of a horse ten years of age.§ It consisted of four distinct portions, and was accompanied by a number of others about the size of a pea, all near the molar teeth and along the zigomatic apophysis. It was ovoid, formed by the union of four distinct portions, each of which was cylindrical and about an inch and a-half in length. It was smooth, whitish externally, and, as it were, polished, internally very white, but with sanguineous spots. It was very hard and form-

* Nicholson's Jour. xiii. p. 374.
† Jour. de Pharm. xiii. p. 626.
‡ Ann. de. Chim. et de Phys. xix. p. 174.
§ Jour. de Pharmacie, xi. p. 465.

ed of concentric layers, very distinct, but having the same colour. It had a nucleus, in the centre of which was a small piece of dog-grass, round which, in all probability, the concretion had formed. It had no taste, but a disagreeable fœtid smell. Its specific gravity was 2·209. Its constituents, according to the analysis of M. Henry, were,

Carbonate of lime,	85·52
Carbonate of magnesia,	7·56
Phosphate of lime,	4·40
Phosphate of magnesia, trace.	
Common salt,	0·04
Organic matter and loss,	2·48
	100·00

3. In 1825, M. Lassaigne analyzed a salivary concretion taken from the duct of the parotid gland of an *ass*, and remarkable for its large size.* It was as big as the fist, its shape was ovoid, its surface smooth and white. Its hardness was about the same as that of marble, and its weight 620 grammes, or very nearly 1 lb. 6 oz. avoirdupois. Its specific gravity was 2·302.

Its constituents, as determined by the analysis of Lassaigne, were,

Water,	3·6
Soluble principles of saliva; soda, animal matter, soluble in alcohol, chloride of calcium, sulphate of lime, &c.	1·0
Mucus,	6·4
Phosphate of lime with trace of iron,	3·0
Carbonate of lime,	85·1
	99·1

From this analysis it appears that the salivary concretion of the ass agrees very nearly with that from the horse, previously examined by M. Lassaigne, and stated above.

4. To M. Lassaigne, also, we are indebted for the chemical analysis of a salivary concretion from a cow. It was white, hard, capable of being polished, about the size of a pigeon's egg, and its nucleus was an oat seed. It consisted of carbonate of lime mixed with a little phosphate of lime and some animal matter. †

5. M. Vauquelin, in 1817, analyzed a concretion found in the

* Ann. de Chim. et de Phys. xxx. p. 332. † Ibid. ix. p. 326.

maxillary gland of an elephant which died in the Museum of Natural History in Paris.* It was white, had a lamellated texture, with some few crystals consisting of regular tetrahedrons. Several such calculi were found in the gland; some of them having an oat seed as a nucleus. They consisted chiefly of carbonate of lime, but contained also phosphate of lime and some animal matter, which performed the part of a cement.

CHAPTER IV.

BILIARY CONCRETIONS.

HARD bodies sometimes form in the gall-bladder, and in their passage through the hepatic duct, being too large for the capacity of that canal, stop up the passage altogether. These concretions got the name of *biliary calculi* or *gall-stones.* They had drawn the particular attention of anatomists, and in 1795 Sœmmering published an excellent monograph on the subject.† Poulletier de la Salle discovered the existence of cholesterin in human biliary calculi, and in 1785 Fourcroy examined a great number, in order to determine whether they were all of the same nature, or whether, like urinary calculi, they were not occasionally composed of different constituents. The investigation was resumed by Thenard in 1806, while occupied with the analysis of bile. He examined gall-stones from oxen and from man.‡ Several gall-stones were analyzed by John in 1811, by Vogel in 1820, by Lassaigne in 1826, by Joyeux in 1827, and by Bally and Henry, Junior, in 1830.

Biliary calculi, as far as they have been examined, may be arranged under the four different classes.

1. The first kind have a white colour, a lamellated structure, and a brilliant crystalline appearance. They are composed of cholesterin. They are generally ovoid, and of the size of a sparrow's egg. Such specimens as I have seen had a yellowish surface, but internally were white. In general only one is found in the gall-bladder at the same time; though to this rule several exceptions exist.

* Jour. de Pharm. iii. p. 208.

† *De concrementis biliariis corporis humani.* ‡ Mem. d'Arcueil, i. p. 59.

2. The second kind are polygonal, because a number of them exist in the gall-bladder at the same time, which causes them to affect each others shape. Externally they have a covering composed of thin concentric layers; within, a matter either crystallized, or having the appearance of coagulated honey. They consist of cholesterin mixed with some choleic acid, probably a little modified in its nature. They vary considerably in their specific gravity: one examined by Dr Bostock had a specific gravity of 0·900* The mean specific gravity of six which I analyzed was 1·061 ; and they all sunk in water.

These calculi, in their composition, differ but little from the last species, since they consist almost entirely of cholesterin. In six gall-stones which I analyzed, this matter amounted to at least $\frac{1}{2}\frac{5}{8}$ths of the whole. The residue was a reddish-brown substance insoluble in alcohol. Nitric acid dissolved it readily, and formed a pink-coloured liquid, from which ammonia threw down no precipitate. Pure potash ley dissolved most of it readily when assisted by heat. From the solution, muriatic acid threw down a dark-green matter, which had a bitter taste, dissolved in alcohol, melted when heated, and exhibited most of the properties of choleic acid. The residue, insoluble in potash, was in grey flakes, and resembled albumen in such of its properties as could be traced. But as it never exceeded $\frac{1}{8}$th of a grain, it was not possible to ascertain its nature with precision.

3. The third kind have a brown colour, and an irregular shape. They are composed of inspissated bile. They are much more common in the gall-bladders of the inferior animals than in that of man.

4. The fourth kind comprehends those gall-stones which do not flame, but gradually waste away at a red heat. Very little is accurately known respecting this kind of calculus. Dr Saunders tells us that he has met with some gall-stones insoluble both in alcohol and oil of turpentine; some of which do not flame, but become red, and consume to an ash like a charcoal.† Haller quotes several examples of similar calculi.‡ Probably they do not differ from the third kind. Two calculi of this kind, very different in their composition, described and analyzed by Orfila and Bally, and Henry, Junior, will be noticed below.

In 1820, M. Vogel examined a human biliary calculus of un-

* Nicholson's Jour. iv. p. 136. † On the Liver, p. 112.

‡ Physiol. vi. p. 567.

common size, passed by stool. It weighed 147·66 grains, and was as big as a nut. It was soft, had a greasy feel, and gave a yellow powder. Its specific gravity was 0·912. It had no sensible nucleus, and internally consisted of crystalline laminæ, having a yellow colour. It consisted chiefly of cholesterin; but contained a little yellowish-brown matter, which became green when treated with muriatic acid.*

In 1827, M. Joyeux analyzed two human biliary calculi also emitted by stool. The first was spherical and of the size of a nut. It was lighter than water, and had no sensible smell. It burnt with a lively flame. Its surface was sprinkled with white spots, which, when viewed under a glass, had a soapy appearance. This calculus consisted of two distinct concentric layers: the external had a brown colour, and was about a line thick, and was composed of crystalline plates. The second layer was two lines thick, had a deep-brown colour, and its crystalline texture was less apparent. In the centre was a nucleus of six lines in diameter. It was lighter coloured than the concentric coats, and was composed of white shining plates. It was composed of,

Cholesterin,	80
Yellow matter of bile,	8
Carbonate of lime,	6
Sulphate of Soda, Oxide of iron, Bile,	6
	100

The concentric layers were composed of,

Cholesterin,	76
Yellow matter,	20
Bile, Sulphate of soda and loss,	4
	100

The nucleus was composed of,

Cholesterin,	84
Yellow matter,	12
Bile, Sulphate of soda and loss,	4
	100†

* Jour. de Pharm. vi. 215.

† Ibid. xiii. 550.

The second calculus had the size of a pigeon's egg. It weighed 92·6 grains, and was lighter than water. It was covered by a brown envelope, which broke by the smallest concussion. It was formed of various concentric layers which had a greenish-yellow colour, and which covered a nucleus of inspissated bile. Its constituents were,

Cholesterin,	4
Yellow matter of bile, .	70
Choleic acid, . .	6
Bile, . . .	8
Green resin, . .	5
Phosphate of lime and magnesia,	3
Oxide of iron and loss, .	4
	100*

This calculus belonged obviously to the third class of gall-stones.

In 1830, MM. Bally and Henry, Junior, analyzed a gall-stone of quite a different nature from the preceding, and seemingly belonging to the fourth set of biliary calculi first noticed by Dr Saunders. It was found in the gall-bladder of a patient who died in the Hotel-Dieu of Paris. It was of the size of a hazel-nut, had an ovoid shape, a white colour, and a soft consistence. Its granular texture exhibited two or three points as if petrified, which, when viewed under the microscope, exhibited a distinct crystallization. It was destitute of smell, and heavier than water. When heated, it was charred without flame, and gradually consumed, leaving a residue of carbonate and phosphate of lime. Its constituents were,

Mucus or albumen, . . .	10·81
Carbonate of lime, . . .	72·70
Carbonate of magnesia, trace.	
Phosphate of lime, . . .	13·51
Oxide of iron, fat, and colouring matter, .	2·98
	100·00†

Another biliary calculus belonging to the fourth kind, but very different in its constitution, had been described by Orfila in

* Jour. de Pharmacie, xiii. 550. † Ibid. xvi. 196.

1812.* It was of the size of a nutmeg. It was deep-green, and its surface was smooth and shining. It burnt away without flaming, giving out a smell like that of horn. It gave a yellow colour to water, was partly soluble in alcohol, and partly in caustic potash. The portion dissolved by water was picromel, that dissolved by alcohol was green matter of bile, and that dissolved by caustic potash was the yellow matter of bile.

The experiments hitherto made upon the gall-stones of the inferior animals are not numerous. Those of oxen, according to Thenard, are always yellow, and consist of the yellow matter of bile, mixed with minute traces of bile, which may be separated by water. When thus washed, they are tasteless, and insoluble in water and alcohol. They are used by painters, though the colour is not permanent but soon changes into brown.†

In 1826, M. Lassaigne gave an account of a gall-stone extracted from a sow.‡ It was composed of,

Cholesterin,	6·
White resin,	44·95
Bile,	3·60
Animal matter and green resin altered,	45·45
	100·00

This constitutes the only example hitherto discovered of a gall-stone of an inferior animal containing cholesterin.

CHAPTER V.

OF OSSIFICATIONS.

The concretions which make their appearance in the solids of the animal body may be comprehended under this name, because they have all a close resemblance to bone, being composed of similar constituents. The following are the most remarkable of these concretions.

1. *Pineal concretions.*—It is well-known to anatomists that small concretions like sand are often found lodged in that part of the brain called the *pineal gland.* It was suspected from ana-

* Ann. de Chim. lxxxiv. 34. † Mem. d'Arcueil, i. 59.
‡ Ann. de Chim. et de Phys. xxxi. 220.

logy, that they consisted chiefly of phosphate of lime, and Dr Wollaston proved the truth of this opinion by a chemical analysis in 1797.* He dissolved some of the sand in nitric acid, and evaporated the solution. Small needleform crystals of phosphate of lime made their appearance.

M. Lassaigne analyzed a concretion from the brain of a horse. It was white, slightly soft, and of the size of a nut. Boiling alcohol extracted from it a little cholesterin. The insoluble portion, constituting the greatest portion of the concretion, consisted of albumen and phosphate of lime.†

2. *Pulmonary concretions.*—It is well known that concretions are occasionally coughed up from the lungs. They are usually enveloped in mucus, and sometimes accompanied by blood, and sometimes not. They may appear without any consumptive tendency. An instance of this is given by Dr Prout.‡ I examined several of these concretions coughed up by a consumptive person, and found them composed of phosphate of lime united to a thick membranous substance, which retained the form of the concretion. The same result had been obtained long before by Fourcroy.§ Dr Henry examined several, and found their constitution the same as I had done. Mr Crampton examined one which he assures us was composed of,

Carbonate of lime, .	82
Animal matter and water,	18
	100‖

One of these concretions examined by Dr Prout consisted chiefly of phosphate of lime, with some carbonate of lime, and an animal matter which retained the size and shape of the concretion after the earthy matter has been removed by an acid.¶

These concretions, so far as I have seen them, are all small; sometimes not larger than a pin-head, and hardly ever reaching the size of a pea. They must be deposited in the bronchiæ or in the air-cells of the lungs.

A concretion examined by Lassaigne, and found in the mesentery of a bull attacked with phthisis, consisted of phosphate of lime mixed with a little carbonate.**

* Phil. Trans. 1797, p. 386.
† Ann. de Chim. et de Phys. ix. 327.
‡ Annals of Philosophy, xiv. 232.
§ Ann. de Chim. xvi. 91.
‖ Phil. Mag. xiii. 287.
¶ Annals of Philosophy, xiv. 233.
** Ann. de Chim. et de Phys. ix. 328.

Lassaigne examined some pulmonary concretions taken from the lungs of a cow labouring under *Phthisis pulmonalis*. They had the form of small white grains, very hard, and united together by a mucous membrane. They consisted of phosphate of lime, mixed with a little carbonate, and deposited in the membrane.*

3. *Hepatic concretions.*—The liver also is sometimes full of similar bodies. The shape of the hepatic concretions, as far as my observations go, is more irregular, and I have seen them of greater size than the pulmonary concretions. By my analysis, they are composed of phosphate of lime and a tough animal membranous matter.

4. *Concretions in the prostate.*—From the experiments of Dr Wollaston we learn that the concretions which sometimes form in the prostate gland have phosphate of lime for their basis.

5. *Concretions in the lachrymal sack.*—According to Fourcroy these concretions, which are very rare, consist of phosphate of lime cemented by a gelatinous matter.†

CHAPTER VI.

OF INTESTINAL CONCRETIONS.

CONCRETIONS of very considerable size are occasionally found lodged in the stomach and intestines; seldom indeed in the human body; but more frequently in some of the inferior animals. Some of these bodies have acquired great celebrity under the name of bezoars. It will be proper to state, in the first place, the facts ascertained respecting concretions found in the human intestines.

Dr Monro secundus, while Professor of Anatomy in the University of Edinburgh, made a pretty large collection of intestinal human calculi, which are still preserved in the Museum of the Anatomy Class. There are a few similar ones among the collection of calculi in the Hunterian Museum of Glasgow, and Dr Marcet informs us that Dr Bostock showed him a similar con-

* Ann. de Chim. et de Phys. ix. 328.

† Mem. de l'Institut. T. iv. as quoted by John, *Tabellen des Thierreichs*, p. 46.

cretion voided by a labouring man in Lancashire.* These concretions on the outside are covered with a thin, whitish, smooth, earthy crust, but when cut open they exhibit a velvety, compact, brownish surface, alternating with concentric laminæ of the white earthy substance. The white laminæ consist of a mixture of phosphate of lime and ammonia-phosphate of magnesia. The velvety substance resists the action of chemical reagents, and burns with the smell of straw. Dr Wollaston, by a microscopic examination of it, found that it consisted of the minute needles or beards which are seen constituting a small brush upon the oat seed when deprived of its husk. It is obvious from this that these concretions can only be formed in the intestines of those persons who use oatmeal as an article of food. Dr Monro used to state in his lectures that when these concretions reached a certain size they blocked up the intestines and proved fatal.

In the London and Edinburgh Journal of Medical Science for September 1841, there is a very interesting case of a man aged 41, who passed fourteen large intestinal concretions similar to those in Dr Monro's collection, together with an excellent and instructive analysis of them by Dr Douglas Maclagan of Edinburgh.

In 1829, M. Colombot, a physician at Chaumont, sent to the Academy of Medicine of Paris, an account of several intestinal calculi voided by stool and of a peculiar kind. M. Caventou received from M. Bourdois other intestinal calculi of the same kind, and subjected them to a chemical examination. When voided they were light, greenish, and translucent, without any regular shape but of a considerable size. When kept for a fortnight in a box they became opaque, grayish white, and exhaled the smell of rancid butter; they reddened tincture of litmus. Hot alcohol dissolved them immediately but left empty vesicles, in which the matter dissolved had been contained. The portion dissolved possessed the characters of stearin.† Lassaigne had long before examined intestinal concretions containing a great quantity of stearin; but they differed from those examined by Caventou in wanting the membranous cyst in which the stearin was confined.‡

Fourcroy and Vauquelin analyzed a great number of intesti-

* Marcet's Essay, p. 129. † Jour. de Pharm. xv. 73.
‡ Ibid. p. 184.

nal concretions or *bezoars*, as they have been termed.* They have divided them into the seven following species, which they have named from the constituents of the respective concretions:

1. Superphosphate of lime.
2. Phosphate of magnesia.
3. Ammonia-phosphate of magnesia.
4. Biliary.
5. Resinous.
6. Fungous.
7. Hairy.

1. *Superphosphate of lime.*—The intestinal concretions belonging to this species are composed of concentric layers, easily separable from each other and very brittle. They redden vegetable blues, and are partially soluble in water. The layers are unequally thick, and differ in their colour.† They were found in the intestines of different mammalia.

2. *Phosphate of magnesia.*—These concretions are uncommon. They are semitransparent, and have usually a yellowish colour. Their specific gravity is 2·160. They are formed of layers less numerous, and not so easily separated as those of the preceding species.‡

3. *Phosphate of ammonia and magnesia.*—This species is the most common of the intestinal concretions. Its colour is gray or brown, and it is composed of crystals diverging like rays from a centre. It has some resemblance to calcareous spar. It contains abundance of animal matter. This species occurs frequently in the intestines of herbivorous animals, as the horse, the elephant, &c.

4. *Biliary.*—This is a species of concretion found frequently in the intestines of oxen, and likewise in their gall-bladder, and employed by painters as an orange-yellow pigment. Its colour is reddish-brown. It is not composed of layers, but is merely a coagulated mass, and appears to be but little different from the matter of bile. When heated it melts. It dissolves readily in alkalies. Alcohol dissolves it partially, and acquires a very bitter taste.§

This species has been already noticed while treating of biliary calculi, to which in reality it belongs.

5. *Resinous.*—To this species belong many of the oriental bezoars, formerly so celebrated, obtained from the intestines of animals with which we are unacquainted. They are fusible and

* Ann. de Mus. d'Hist. Nat. iv. 331.
† Ibid. i. 102, and iv. 331.
‡ Ibid. iv. 332.
§ Ibid. iv. 333.

combustible, composed of concentric layers, smooth, soft, and finely polished.* Fourcroy and Vauquelin have distinguished two varieties; the first of a pale-green colour, a slightly bitter taste, almost completely volatile; giving by heat a solid tenacious matter, soluble in alcohol, and separating in crystals as the solution cools. This matter consists partly of bile, partly of resin. The second variety has a brown or violet colour; its taste is not bitter; it does not dissolve in alcohol, but is soluble in alkalies. The solution becomes purple-red when allowed to dry in the open air. When distilled it yields a yellow sublimate, having the smell and taste of soot, and insoluble in water and alcohol.†

6. *Fungous.*—This species consists of concretions composed of pieces of the *Boletus igniarius*, disposed in layers, and cemented by an animal matter. These pieces had been doubtless swallowed by the animals in whose intestines they were found.‡

7. *Hairy.*—Balls of hair felted together, sometimes pure, sometimes covered with animal matter, and sometimes mixed with vegetable remains, occur very frequently in the intestines of animals.‡

8. *Ligniform.*—This eighth species must be added in consequence of the experiments of Berthollet. Among the presents sent to Bonaparte by the King of Persia were three bezoars, which were consigned to Berthollet for analysis. They all belonged to this species. They had an oval shape, and a very smooth surface. Their colour externally was greenish-black, internally brown. They were formed of irregular concentric layers. In the centre of one was found a collection of straws and other vegetable fragments; in that of the other, small pieces of wood about the size of a pin. Their specific gravity was 1·463. They were insoluble in water, alcohol, and diluted muriatic acid. Potash ley dissolved them readily, and they were thrown down unaltered by muriatic acid. When distilled they yielded the products of wood, and left a quantity of charcoal in the retort, which, when incinerated, gave traces of sulphate of soda, muriate of soda, lime, and silica. Thus it appears that they possessed all the properties of pure woody fibre. They must have been formed in the stomach of the animals, and not in the alimentary canal.§

* Ann. de Mus. d'Hist. Nat. iv. 334. † Ibid. 335. ‡ Ibid. 336.
§ Mem. d'Arcueil, ii. 48.

To these intestinal concretions may be added one found in a scirrhus situated in the meso-colon (an organ connected with the large intestines) of a mare, and examined by Lassaigne. It was yellowish, greasy to the feel, had the odour of rancid oil, and strongly stained blotting-paper. It was a mixture of albumen and a peculiar matter, consisting partly of cholesterin, and partly of a white substance, crystallizing in needles, and reddening vegetable blues. When this concretion was calcined it yielded phosphate and carbonate of lime.*

In the year 1827, I received from Dr Vallance of Strathaven a very large intestinal calculus from a horse. When taken out it weighed above four troy pounds, or very nearly five pounds and a-half avoirdupois. It measured 20 inches round its greatest circumference, and 18 inches round its lesser. When cut through the centre, it exhibited a set of concentric layers of the husk of oats, mixed with some straws and hay. These layers were separated from each other by thinner white layers, consisting chiefly of subsesquiphosphate of lime. In the centre of the calculus there was a little piece of hard stone, which seems to have served as a nucleus.

This calculus had a specific gravity of 1·609. When dried on the steam-bath, it lost 35·22 per cent. of its weight. A portion thus dried being subjected to analysis was found composed as follows:

Lost by ignition,	40·73 †
Phosphate of lime,	41·01
Carbonate of lime,	0·41
Carbonate of magnesia,	5·28
Carbonate of potash,	2·32
Earthy insoluble matter,	9·80
	99·55

M. Girardin analyzed in 1840 an intestinal concretion from a horse.‡ The horse belonged to a miller, who lost five horses in a short time, in all of which many intestinal concretions were found. The horses were fed with bran; and M. Lassaigne had observed, that several asses which had been fed with bran had

* Ann. de Chim. et de Phys. ix. 329.

† This loss was occasioned by burning the oat beards and the hay and straw visible in the calculus.

‡ Jour. de Pharm. xxvi. 420.

died from intestinal concretions composed of ammonia-phosphate of magnesia.

The calculus analyzed by Girardin was triangular with its edges and surface smoothed; showing that it had existed along with other calculi in the intestines. It was of the size of a large apple. It weighed 311 grammes. Its texture was crystalline, its colour brown, and its specific gravity 1·741. Its constituents were,

Water,	14·0
Ammonia-phosphate of magnesia,	48·0
Phosphate of lime,	19·0
Animal matter, insoluble in acid and water,	0·8
Matters soluble in water,*	6·6
Extractive soluble in alcohol,†	4·0
Fatty matter,	7·0
	99·4

M. Schwerkert, apothecary in Dingelstadt, has also given an account of an ammonia-phosphate of magnesia calculus found after death in the cæcum of a horse.‡

There are four calculi in the Hunterian collection in Glasgow composed of *lithofellic acid.* They are oval-shaped, and composed of concentric layers. The largest is about two inches in length and one inch in thickness, and weighs about 320 grains. One of these calculi has for a nucleus a date-stone; the nucleus of another is a vegetable substance resembling matted hair. Hence they would seem to be intestinal concretions of some inferior animal,—probably bezoars.

DIVISION III.

OF THE FUNCTIONS OF ANIMALS.

The object of the preceding part of this work has been to exhibit a view of the different substances which enter into the composition of animals, as far as the present limited state of our

* Albuminate of soda, common salt, alkaline sulphates, salts of lime and magnesia.

† With common salt, salts of magnesia, and fatty matter.

‡ Ann. der Pharm. xxxvii. 200.

knowledge puts it in our power. But were our inquiries concerning animals confined to the mere ingredients of which their bodies are composed, even supposing the analysis as complete as possible, our knowledge of the nature and properties of animals would be imperfect indeed.

How are these substances arranged? How are they produced? What purposes do they serve? What are the distinguishing properties of animals, and the laws by which they are regulated.

Animals resemble vegetables in the complexness of their structure. Like them, they are machines nicely adapted for particular purposes, constituting one whole, and continually performing an infinite number of the most delicate processes. But neither an account of the structures of animals, nor of the properties which distinguish them from other beings, will be expected here: these topics belong entirely to the anatomist and physiologist. I mean in the present Division to take a view of those processes only that are concerned in the *production* of animal substances, which alone properly belong to Chemistry. The other functions are regulated by laws of a very different nature, which have no resemblance or analogy to the laws of Chemistry or Mechanics.

CHAPTER I.

OF DIGESTION.

Every living being constitutes a complicated machine, composed of a great variety of parts, all of which conspire to produce certain ends calculated for the benefit of the whole. The waste which is continually going on is repaired by the conversion of the food into all the different substances which make up the whole of the living structure. This extraordinary but necessary process is distinguished by the name of *digestion*.

In man and the larger animals the food passes through a number of tubes or canals, and gradually during the course of its progress assumes the form of blood. This blood circulates through appropriate vessels, and supplies the waste of every organ in the body. Bony matter for the bones, muscular matter for the muscles, nervous matter for the brain, &c. or it passes through certain tubes, constituting the matter of which *glands* are composed, and during its progress it is converted into the various se-

cretions, useful or indispensable for the animal economy. In this way are formed the seminal fluid of the male, the milk of the female destined for the nourishment of the offspring; and in this way are formed the saliva, the bile, the pancreatic juice, the mucous matter which lines the cavities of the body, and all the different secretions so indispensable for the use of the living animal.

How these changes are induced has hitherto eluded the utmost sagacity of physiologists. But, in man and the greater number of animals, the agency of the nervous filaments which are spread through all the essential organs of the body, is indispensable. Accordingly, when these nerves are cut or diseased, the organ which they supply ceases to perform any of its functions. Hence in man and in most animals, we may say that the nervous energy, whatever it may be, constitutes the indispensable part of the living structure. Yet it cannot be maintained that life cannot exist without nerves; for *plants* are undoubtedly living beings. They require food and digest it, just as animals do; and the digested food is afterwards applied to all the purposes of secretion and assimilation, just as in animals. Yet nothing like nervous structure has ever been observed in vegetables; nor is there the least reason for supposing them supplied with nerves.

The digestion of food, or the conversion of it into blood, though we are utterly incapable of imitating it by artificial processes, is purely a chemical process. We can only expect to learn the contrivances which nature follows in it by investigating the different changes which the food undergoes as it passes in succession through the different organs employed in digestion, and by ascertaining the chemical nature of the different substances which are employed in the successive steps by which the food is converted into blood.

Let us then examine in succession the changes which the food undergoes, and the liquids employed in producing these changes. We must confine ourselves chiefly to the human species, though a very great proportion of the facts which have been acquired were obtained by experimenting upon the inferior animals, particularly dogs, whose food and whose organs of digestion bear a close resemblance to those of the human body.

The food of man is of two kinds, partly animal and partly vegetable; and the structure of his teeth shows that nature intended him to make use of both. The vegetable substances which answer best for food are, *sugar*, *gum*, and *starch*. And, as has been well observed by Dr Prout, those vegetable substances are

the most nutritious which contain all the three mixed in the requisite proportions. None of the three are often exhibited by nature in a state of purity. They are extricated from various plants by artificial processes, more or less intricate and laborious. Pure sugar was shown by Magendie not to be capable of supporting the life of dogs. He fed them upon refined sugar. They swallowed the food with avidity, yet they became lean and thin, and exhibited all the symptoms of animals in a state of starvation. After some weeks, ulcers broke out in the cornea, first of one eye and then in the other. These ulcers went on increasing till they penetrated the cornea, and the liquors of the eye were discharged by them. The dogs expired about the 32d day in a state of complete exhaustion.*

It would have been more satisfactory had this experiment been made in a different manner. The dog is accustomed to live entirely, or nearly so, on animal food. Hence the stomach and intestines of these animal not being accustomed to vegetable food, might not be able all at once to digest it. It is possible that, had the change been induced sufficiently slowly, dogs might at last be brought to live upon sugar. Yet it cannot be doubted, that had loaf bread been substituted for sugar, and that if the dogs had been allowed to eat of it *ad libitum*, and at the same time had been supplied with a sufficient quantity of water, the change of diet, though it might not have been relished, and though the animals might not have thriven on it, yet would not have occasioned death. The juice of the sugar cane, in which the sugar is mixed with mucilage and albumen, is a nutritive article of food. For it is said that the negroes in the West Indies get fat from the unrestrained use of the juice during the season in which raw sugar is manufactured.

The animal matter, which seems to constitute the most nutritious article of food, is a proper mixture of gelatin, albumen, and fibrin, together with a certain portion of fat, as they exist in the flesh of a well-fed ox or sheep.

The use of animal food alone seems to have a tendency to bring the body into an unhealthy state. As that dreadful disease, the sea-scurvy, is the usual consequence of it, at least when the meat is salted. A restriction to vegetable food does not seem by any means so injurious. Many persons who restricted

* Ann. de Chim. et de Phys. iii. 66.

themselves to it have enjoyed good health for years. Indeed in some parts of the world, Hindostan for example, animal food is abstained from on account of a religious scruple, and yet the inhabitants enjoy health.

Wheat flour seems one of the most nourishing articles of vegetable food. In the northern parts of India, where the population live upon wheat, the inhabitants are said to be a stouter and more hardy race than those who live in the south, where the food is rice. But perhaps other circumstances besides the different quantity of nourishment in wheat and rice may intervene to constitute this difference.

We have a number of interesting experiments by Sir Astley Cooper, on the relative digestibility of various articles of food.

To understand the way in which these experiments were made, it is necessary to state that the food in the stomach is dissolved in the gastric juice, and that the difficulty of digestion is considered as proportional to the length of time which elapses before the food in the stomach is dissolved. If, therefore, we put a given weight of any food into the stomach of an animal, allow it to remain a certain time and then weigh it again, it is clear that the food which weighs least will be the most digestible. Sir Astley Cooper made his experiments on dogs. Given weights of the respective articles were put into the stomach of the dog. After a certain interval he was killed, and the proportion remaining undissolved in the stomach determined. Raw food and the lean parts only of meat were given, except when the contrary is expressed:

Experiment 1st.

Kind of food.	Form.	Quantity.	Animal killed after.	Loss by digestion.
Pork,	Long and narrow.	100	1 hour.	10
Mutton,	Do.	100	Do.	9
Veal,	Do.	100	Do.	4
Beef,	Do.	100	Do.	0

Experiment 2d.

Kind of food.	Form.	Quantity.	Animal killed after.	Loss by digestion.
Mutton,	Long and narrow.	100	2 hours.	46
Beef,	Do.	Do.	Do.	34
Veal,	Do.	Do.	Do.	30
Pork,	Do.	Do.	Do.	20

Experiment 3d.

Kind of food.	Form.	Quantity.	Animal killed after.	Loss by digestion.
Pork,	Long and narrow.	100	3 hours.	98
Mutton,	Do.	Do.	Do.	87
Beef,	Do.	Do.	Do.	37
Veal,	Do.	Do.	Do.	46

Kind of Food.	Form.	Quantity.	Animal killed after	Loss by digestion.
	Experiment 4th.			
Pork,	Long and narrow.	100	4 hours.	100
Mutton,	Do.	Do.	Do.	94
Beef,	Do.	Do.	Do.	75
Veal,	Do.	Do.	Do.	69
	Experiment 5th.			
Cheese.	Square.	100	4 hours.	76
Mutton,	Do.	Do.	Do.	65
Pork,	Do.	Do.	Do.	36
Veal,	Do.	Do.	Do.	15
Beef,	Do.	Do.	Do.	11
	Experiment 6th.			
Beef,	Long and narrow,	100	2 hours.	0
Rabbit,	Do.	Do.	Do.	0
Cod fish,	Do.	Do.	Do.	74
	Experiment 7th.			
Cheese,	Long and narrow.	100	2 hours.	29
Fat,	Do.	Do.	Do.	70
	Experiment 8th.			
100 beef,	...	...	...	100
100 potatoes,	...	...	...	48
	Experiment 9th.			
Roast veal,	Long and narrow.	100	...	7
Boiled do.	Do.	Do.	...	30
	Experiment 10th.			
Roast veal,	Long and narrow.	100	...	2
Boiled do.	Do.	Do.	...	31
	Experiment 11th.			
Muscle,	...	100	4 hours.	36
Skin,	...	Do.	Do.	22
Cartilage,	...	Do.	Do.	21
Tendon,	...	Do.	Do.	6
Bone,	...	Do.	Do.	5
Fat,	...	Do.	Do.	100
	Experiment 12th.			
Thigh-bone,	...	100	3 hours.	8
Ditto,	...	Do.	6½ hours.	30
Scapula,	...	Do.	6 hours.	100*

It would appear from the experiments that pork is the most digestible of the common meats in the stomach of the dog. In the human stomach, when weakened, the order of digestibility seems to be mutton, beef, veal, pork. But we must recollect that these articles of food were given to the dog in a raw state, while before they are introduced into the human stomach they have been either roasted or boiled. From experiments 9 and 10, it ap-

* Dodsley's Annual Register, 1823, p. 285.

pears that boiled veal is more easily digested than roasted; and from experiment 6, that cod-fish is much more digestible than either beef or rabbit. From experiment 5th, it appears that cheese is more digestible than meat; and from experiment 7th, that fat is much more digestible than cheese. Experiment 8th shows us that beef is more easily digested than potatoes.

Dr Stark made a great number of experiments on himself. He lived a fortnight on bread and water; and found that during that time the weight of his body had diminished by 3 lbs. He lived a month on bread, sugar, and water, and during that interval his body became lighter by 3½ lbs. He substituted olive oil for the sugar; but the change producing purging and injuring the health, he was obliged to give it up. Milk being substituted, for the oil was found to agree better, though he still lost weight. Bread, water, and roasted goose seemed to agree with him perfectly. He tried bread, water, and boiled beef; stewed lean of beef with gravy and water; the same with the addition of suet; flour, oil of suet, water and salt; flour, fresh butter, water and salt; yolk of eggs, suet, figs, and water; flour, oil of marrow, water, and salt; bread with roasted fowl, infusion of tea and sugar; bread, stewed lean of beef with gravy, infusion of tea with sugar; bread, the fat of stewed beef with jelly, water and salt; bread, fat of bacon ham, infusion of tea with sugar, &c. These experiments he continued for more than half a year. The consequence was the destruction of the tone of the stomach and a fever which speedily carried him off. Scarcely any conclusion can be drawn from these experiments; except the danger of persisting in an aliment which is particularly offensive to the stomach; and the necessity of varying the food if we wish to enjoy good health.*

From the numerous experiments of Tiedemann and Gmelin, it seems to follow that animal food is more easily digested by dogs than vegetable food.†

Every body knows that in man and all the more perfect animals the food is introduced into the mouth, where it is comminuted by the teeth, and mixed up into a kind of magma or pulp by means of the *saliva*.

* The works of W. Stark, M. D. p. 89.

† *Recherches Experimentales, Physiologiques, et Chimiques sur la Digestion*, p. 178.

An account of the saliva has been given in a preceding chapter of this work, to which the reader is referred for a minute detail of its chemical properties.

It is a liquid nearly colourless, somewhat viscid, and usually containing a few white flocks, which gradually sink to the bottom when the saliva is left at rest in a vessel. It is thrown into the mouth from the salivary glands, when it is secreted, and in greatest abundance during the mastication of the food. The whole amount of it in twenty-four hours from an adult individual is about seven ounces and a-half avoirdupois.*

Human saliva, when dried in the vacuum of an air-pump over sulphuric acid, leaves 1·62 per cent. of solid residue. These 1·62 parts contain 0·421 of the white flocks which may be considered as mucus. They contain 0·528 of a matter soluble in water, but insoluble in alcohol of 0·863. This is the substance to which the name of *salivin* has been given, and the properties of which have been described in a former chapter of this volume. Its use in digestion has not yet been ascertained; but, as it possesses the characters of a weak acid, it is highly probable that it facilitates the conversion of the food into chyme in the stomach.

The 1·62 of insoluble residue contains also 0·444 of a matter soluble in water; but insoluble in alcohol of 0·800. This matter consists chiefly of chlorides of potassium and sodium: but is not quite free from salivin. The residue of the 1·62 amounting to 0·288 is soluble both in water and in alcohol at 0·800. It consists chiefly of lactate of soda, and of soda combined with mucus, but is not quite free from salivin.

Thus the solid contents of healthy saliva from 100 parts of that liquid are,

Mucus,	.	0·421
Salivin,	.	0·528
Salts,	.	0·732
		1·681

In this analysis, which was made by Mitcherlich, there is an excess of 0·061.

The great use of the saliva is doubtless to lubricate the food, and cause it to descend easily into the stomach; but it is probable that the salivin which it contains contributes somewhat to the conversion of the food into chyme. Accordingly, it appears

* Poggendorf's Annalen, xxvii. p. 320.

from the experiments of Eberle, Muller, and Schwann, that certain articles of food, when put into glass tubes containing saliva, and kept at the temperature of 100°, are dissolved. This, in particular, is the case with starch, which, by digestion in saliva, is converted into gum and sugar.

The food thus ground down by the teeth and moistened by the saliva, passes along the œsophagus into the stomach, which is a strong membranous and muscular bag, situated in the upper part of the abdomen, immediately below the diaphragm, and rather more inclined to the left than the right side, especially when distended with food. The innermost or villous coat is said to be larger than the other coats, and therefore to be wrinkled into folds; but this is not very evident on dissection, if we except the fold distinguished by the name of the valve of the pylorus.

In the stomach the food undergoes a farther change, being converted into a kind of pap, called *chyme*. The food, after mastication in the mouth, still retains its sensible qualities, and may be recognized by the colour, taste, and smell which it possessed before mastication; but when food is converted into chyme its sensible qualities are altered. We can no longer recognize the kind of food which has been taken into the mouth. This change of the food into *chyme* is the first step in the process of digestion—a step altogether performed by the stomach.

It seems to follow from the observations of Dr Wilson Philip that in rabbits, which live entirely on vegetable food, those parts only of the food are changed into chyme which come in contact with the internal coat of the stomach. This organ, in consequence of its muscular coat, appears to be in motion, similar to the peristaltic motion of the intestines, during the whole process of ventricular digestion. By this motion those portions of the food which have been converted into chyme are pushed forward towards the pyloric orifice, and new portions of the food come in contact with the stomach to undergo a similar change.

From the experiments of Dr Stevens it is evident that in the human stomach food may be converted into chyme without coming in contact with its innermost coat.* His experiments were made upon a man who supported himself by swallowing stones for money. He had accustomed himself to this practice from

* See his Thesis *De Alimentorum concoctione*, printed in Edinburgh in the year 1777. It was inserted in the first of the four volumes of theses published in Edinburgh by Elliot in 1786.

the age of seven, and had continued at it for twenty years. His stomach was so much distended that he could swallow many stones at once. They could not only be felt in his stomach, but when he struck the hypogastric region of the abdomen they might by the bystanders be heard to rattle. Dr Stevens inclosed in silver perforated spheres $2\frac{1}{2}$ inches long, and $3\frac{1}{4}$ inches in circumference, various kinds of food. The spheres were evacuated about twenty hours after being swallowed, and it was in Dr Stevens's power to ascertain what change the food had undergone. A few of the experiments will enable the reader to judge of the results. $4\frac{1}{2}$ scruples of raw beef lost $1\frac{1}{2}$ scruple of their weight. The silver sphere was divided into two compartments. Into the one was put 1 scruple 4 grains of raw beef, and into the other 4 scruples 8 grains of boiled beef. The sphere was voided in forty-three hours. The raw beef had lost 1 scruple 2 grains of its weight; the boiled beef 1 scruple and 16 grains.

Silver spheres were now employed, the numerous perforations in which were of the size of a crow quill. The following were the experiments made:

Substances introduced.	Length of time before voided.	Result.
Beef slightly masticated,	38 hours.	All dissolved.
Raw pork,	45	Ditto.
A piece of cheese,	45	Ditto.
Roast pheasant,	46	Ditto.
Salt herring,	46	Ditto.
Raw parsnep,	48	Ditto.
Raw potato,	48	Ditto.
Raw turnip,	36	Ditto.
Boiled turnip,	36	Ditto.
Apple, raw,	36	Ditto.
Do. boiled,	36	Ditto.
Grains of rye,	Many hours.	Not altered.
wheat,	Do.	Ditto.
barley,	Do.	Ditto.
oats,	Do.	Ditto.
Peas,	Do.	Ditto.
Thigh-bone of sheep,	48	Ditto.
Wing of pheasant,	48	All dissolved except the bones.
Living leech,	...	All dissolved.
Living lumbricus,	...	Ditto.

Dr Stevens proved likewise by his experiments that the stomach of certain animals—the dog, for example, acted more powerfully upon animal than on vegetable food. On the contrary, the stomach of the sheep and ox acted powerfully on vegetable food, while it produced no sensible alteration on animal food. This will be evident from the following experiments:

I. *The Dog.*

Food inclosed in spherules.	Hours in the stomach.	Loss of weight.
17 parts raw beef,	4	5 parts.
Do. raw cod, .	4	9
Do. raw potato, .	4	3
Do. raw cabbage,	4	1
Do. roast mutton,	4	6
Do. boiled turbot,	4	10
Do. parsnep, .	4	0
Do. boiled potato,	4	5

The food was inclosed in perforated ivory spheres. The ivory was obviously corroded. This induced Dr Stevens to make the following experiments:

17 boiled mutton, .	8 hours.	All dissolved.
Do. fish, .	Do.	Do.
Do. potato, .	Do.	11 parts.
Do. parsnep, .	Do.	0

The ivory balls in which these articles had been inclosed were dissolved and had disappeared. He then made a dog swallow three pieces of the thigh-bone of a sheep. In seven hours,

The 1st fragment lost 7 grains of its weight.
2d ... 9
3d ... 12

In the following experiments made on the stomach of the dog the articles of food tried were enclosed in perforated tin-cases, which were not in the least acted on:

		Weight lost.
17 parts roast beef, .	10 hours.	All dissolved.
Do. roast veal, .	Do.	10 parts.
Do. tallow, .	Do.	8 do.
Do. wheat bread,	Do.	All dissolved.
Do. roast mutton,	7 hours.	Do.
Do. roast lamb,	Do.	10 parts.

			Weight lost.
17 parts raw beef,	.	Do.	10 parts.
Do. roast beef,	.	Do.	All dissolved.
Do. raw cod,	.	Do.	14 parts.
Do. boiled cod,	.	Do.	All dissolved.
Do. roast beef,		.	Do.
Do. roast mutton,		.	Do.
Do. roast fowl,		.	11 parts.

We see from these trials that in the dog's stomach old meat is more easily digested than that of young animals, and that roasted or boiled meat and fish are more easily digested than when in a raw state.

II. *The Sheep.*

Raw beef, .	6 hours.	Unchanged.
Raw salmon. .	Do.	Unchanged.
Raw radish, .	Do.	All dissolved.
Raw potato, .	Do.	All dissolved.

When the experiments were repeated with the same articles boiled, the result was the same.

III. *The Ox.*

Beef, .	10 hours.	Unchanged.
Fish, .	Do.	Unchanged.
Hay, .	Do.	All dissolved.
Cabbage, .	Do.	All dissolved.

Similar experiments were made by Reaumur and Spallanzani ; but it is unnecessary to state them, because the results were nearly the same.

It will now be proper to describe somewhat in detail the phenomena which take place in the stomach during digestion. This cannot be done better than by stating the observations made by Dr Prout on the subject.*

1. *Digestion in the Rabbit.*—A rabbit, which had been kept from food for twelve hours, was fed upon a mixture of *bran* and *oats*. About two hours afterwards it was killed, and examined immediately while still warm. The stomach was moderately distended with a pulpy mass, which consisted of the food in a minute state of division, and so intimately mixed, that the different articles of which it was composed could be barely recognized. The digestive process, however, did not appear to have taken

* Annals of Philosophy, (1st series), xiii. 13.

place equally throughout the mass, but seemed to be confined principally to the superficies, or where it was in contact with the stomach.* The smell of the mass was peculiar, and difficult to describe. It might be called weak but disagreeable. On being wrapped up in a piece of linen, and subjected to moderate pressure, it yielded upwards of half a fluid ounce of an opaque, reddish-brown fluid, which instantly reddened litmus-paper very strongly, though not permanently, as, upon being dried or even exposed to the air for a short time, the blue colour was restored. It instantly coagulated milk and redissolved the curd, converting it into a fluid similar to itself. It was not coagulated by heat or acids, and therefore contained no *albumen*. On being evaporated to dryness, and incinerated, it left an alkaline chloride with traces of an alkaline phosphate and sulphate, together with sulphate, phosphate, and carbonate of lime.

2. *Digestion in the Pigeon.*—The bird was young, but fully fledged, and had been fed about two hours before it was killed upon a mixture of barley and peas. It was opened and examined immediately after death. In the *crop* was a portion of food which was swollen and soft, but appeared to have undergone no farther sensible change than might have been expected from mere heat and moisture. This organ did not exhibit any evidence of the presence of an acid. The *gizzard* or stomach contained corn in various states of decomposition, the internal parts of some of the seeds being reduced to a milky pulp, which flowed out on their being subjected to pressure; others were reduced to a mere husk, while others were in various states between these two extremes. The whole contents of the stomach exhibited decidedly acid properties. But the litmus-paper recovered its blue colour again almost instantly after exposure to the atmosphere. They coagulated milk, but yielded no trace of albumen.

3. *Digestion in the Tench and Mackerel.*—The contents of the stomach and upper intestines of the *tench* were examined immediately after death; but, as the fish had been kept for some time in an unnatural state, the phenomena were not quite satisfactory. The contents of the stomach and upper portion of the intestines consisted of little more than a yellowish glairy fluid, which seemed to be bile; and the small quantity of alimentary

* This corroborates Dr Wilson Philip's statement noticed above.

matters present appeared to be unnatural, and little capable of being acted upon by the digestive organs. No traces of albumen could be found.

The mackerel examined had just come from the coast where it had been caught the day before. The stomach was nearly filled with a whitish grumous mass, in which the undigested bony remains of some small fish were visible. This mass very faintly reddened litmus, and, by the assistance of heat, coagulated milk. It underwent a partial coagulation by the acetic or other acids, especially when heat was applied; but no traces of albumen could be perceived in it.

Physiologists seem to have been generally of opinion that the stomach contained an uncombined acid, somehow connected with the process of digestion, till Spallanzani concluded, from a great number of experiments, that the gastric fluid, when in its natural state, is neither acid nor alkaline. In the year 1823, Dr Prout ascertained by numerous experiments that a free acid exists in the stomach of the rabbit, the hare, the horse, the calf, and the dog, and also in the liquid ejected from the human stomach in cases of dyspepsia. He washed the contents of a rabbit's stomach with distilled water, and divided the aqueous liquid into four equal portions. The first was evaporated to dryness, and the residuum incinerated. It was then redissolved, and the chlorine which it contained was determined by means of nitrate of silver. The second portion was supersaturated with potash, evaporated to dryness, ignited, and its quantity of chlorine determined by nitrate of silver. This gave the whole chlorine in the contents of the stomach. The third portion was exactly neutralized by a solution of potash of known strength. This gave the quantity of free muriatic acid in the stomach. And from these data the quantity of sal-ammoniac was calculated. The following table will show the result of three experiments on the gastric juice of rabbits:

	No. 1. Grains.	No. 2. Grains.	No. 3. Grains.
Muriatic acid combined with fixed alkali, .	0·12	0·95	1·71
Ditto with ammonia, . .	1·56	0·76	0·40
Ditto uncombined, .	1·59	2·22	2·72
Total,	3·27	3·93	4·83

The following table shows the quantity of muriatic acid in one pint of the acid fluid ejected from the human stomach in three cases of dyspepsia :

	No. 1. Grains.	No. 2. Grains.	No. 3. Grains.
Muriatic acid combined with a fixed alkali,	12·11	12·40	11·25
Ditto with ammonia, . . .	0·00	0·00	5·39
Ditto free, . .	5·13	4·63	4·28
Total,	17·24	17·03	20·92*

These conclusions have been objected to by Leuret and Lassaigne, because, in their opinion, the excess of potash employed in examining the second portion of the liquid would react upon the azotic substances present during the calcination, and cyanodide of potassium and carbonate of potash would be formed. These substances would cause a precipitation of the nitrate of silver, which would increase the apparent quantity of muriatic acid present.† But it is impossible to doubt that Dr Prout saturated the excess of potash with an acid (probably nitric,) before he precipitated the muriatic acid by nitrate of silver.

The results of Prout were confirmed by the experiments of Tiedemann and Gmelin in 1826.‡ They distilled the liquid in the stomach of dogs and horses, and found generally free muriatic acid, together with a quantity of acetic acid, and sometimes of butyric acid. There was much acetic acid in the stomach of a dog which had been made to swallow pepper. They found the same acid in the gastric juice of a horse which had been made to swallow pebbles. They twice found butyric acid in the gastric juice of a horse.

Tiedemann and Gmelin examined the liquids in the stomachs of no fewer than 43 animals, dogs, cats, horses, oxen, calves, and sheep. It was acid in every case, and the quantity of acid was always considerable. The acids were usually two in number, namely, the muriatic and acetic. In ruminating animals they found also butyric acid.

Leuret and Lassaigne assure us that, when stimulants are applied to the innermost coat of the stomach or duodenum of a

* Phil. Trans. 1824, p. 45. † Recherches Physiologiques, p. 116.
‡ Recherches Experimentales, &c. i. p. 91.

living animal, there is always a discharge of a liquid from the villous extremities so abundant in that coat. This liquid, discharged only when stimulating bodies are applied, or by the stimulus of food, is, no doubt, the gastric juice, by the agency of which the food is converted into *chyme*. It was shown decisively by the experiments of Dr Stevens, that this juice acts by dissolving the food, and that it produces the same effect upon food out of the body, provided the temperature be kept at 100°, as in the stomach.

Dr Beaumont of the United States army had an opportunity of witnessing the process of digestion, and the appearance of the gastric juice in the stomach of Alexis H. Martin, who had a perforation of the stomach, occasioned by a shot. The orifice gradually healed; but remained open with a kind of valve opening from without, by means of which any thing could be introduced into the stomach, and, by pushing the valve aside, the appearance of the inner coat of the stomach and of the gastric juice could be examined, and quantities of the gastric juice itself could be extracted, and its nature ascertained. The facts ascertained by Dr Beaumont have been stated at considerable length in a preceding chapter of this work, to which the reader is referred.

The gastric juice, as observed by Dr Beaumont, was a pure, limpid, colourless, slightly viscid fluid. It exhaled a weak odour, not disagreeable, but slightly aromatic. Its taste was feebly saline, and it always contained an uncombined acid, which Dr Prout first showed to be the muriatic. The true gastric juice is secreted only during digestion, and does not exist in the stomach at any other time. What was taken for it by Spallanzani and other experimenters towards the end of the eighteenth century, was merely the saliva mixed with the mucus, secreted to lubricate the stomach, and protect it from the action of certain substances sometimes present, which might otherwise injure it.

From the experiments of Eberle, Müller, and Schwann, formerly stated, it follows that the gastric juice contains also another substance, called *pepsin*, some of the most remarkable properties of which have been detailed in a preceding chapter of this work. It is by the united action of the muriatic or acetic acid of the gastric juice, and of the pepsin which it contains, that the food in the stomach is converted into chyme.

When casein, gelatin, or gluten is put into water, acidulated

with muriatic or acetic acid, and kept at the temperature of 100°, solution takes place, and the gelatin loses its property of gelatinizing, and of being precipitated by chlorine. But these acidulated liquids are incapable of dissolving coagulated albumen or fibrin, and likewise to a certain extent casein. To make an artificial juice capable of dissolving these very common articles of food, a portion of the third and fourth stomachs of an ox was digested for twenty-four hours in water, containing 2·75 per cent. of muriatic acid. It contained in solution 2·75 per cent. of solid matter. A portion of this solid matter was pepsin. For when the liquid thus prepared was digested for some hours on coagulated albumen in powder, a complete solution was obtained.

It would appear from the present knowledge possessed by physiologists, that the gastric juice, besides salivin, contains a certain quantity of muriatic acid and pepsin. This liquid, in consequence of the temperature and the peristaltic motion of the stomach, gradually dissolves the food into an opal-coloured and adhesive liquid called *chyme.*

The chyme thus formed passes into the duodenum, where it is gradually separated into two distinct substances. 1. A milky liquid, which is absorbed by the lacteals, under the name of *chyle*, and a quantity of excrementitious matter, which gradually makes its way along the intestinal canal, and at last is thrown out of the body altogether.

According to Leuret and Lassaigne, a portion of chyle is formed in the stomach itself. They assure us that, if the stomach of a living animal be opened during digestion, the white vessels or lacteals of the stomach are easily seen. They inform us that they have collected chyle from the lacteals in the stomach of the horse, and ascertained by experiment that it possesses the usual properties of that liquid.*

These gentlemen affirm also that, if the duodenum of a living animal be opened, and a stimulating substance, as vinegar, applied to its villous coat, a quantity of liquid is immediately secreted, similar in appearance to the gastric juice of the stomach.† If this be a correct statement of facts, there can be little doubt that the liquor given out by the villous coat of the duodenum during digestion is destined to act upon the chyme, and to assist

* *Recherches sur la Digestion*, p. 124. † Ibid. p. 140.

in converting it into *chyle*. But, as the liquid of the duodenum has never been collected nor examined in a state of purity, little is known respecting its nature.

Leuret and Lassaigne made a hungry dog swallow small pieces of sponge wrapt up in fine linen. The animal was killed twenty-four hours after. Some of the sponges were found in the stomach, and some in the duodenum. The sponges in the stomach contained a mucous, whitish acid liquid; those in the duodenum a liquid which was yellowish, but little viscid, and but weakly acid. A quantity of this last liquid was mixed with crumb-of-bread in a phial, and kept for some hours in a temperature of 88°. In eight hours the bread disappeared, and there remained a thick homogeneous yellowish liquid, in which iodine detected the presence of a little starch.* But we have no evidence that the liquor thus examined was secreted by the duodenum. Undoubtedly the sponges would remain for some time, and would imbibe liquid in the stomach.

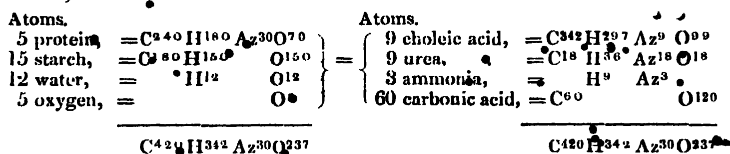
There are two liquids which are poured into the duodenum, and which are generally considered as intimately connected with the conversion of the chyme into chyle. These are the *pancreatic juice* and the *bile*. An account of both of these liquids, so far as they have been investigated, has been given in a preceding part of this work.

The *pancreatic juice* is not abundant. It was long considered as similar to saliva; but later investigations have shown that its nature is different. It is weakly acid, and contains pancreatin and casein; but the function of these substances in the process of digestion or of the conversion of the chyme into chyle is not yet understood.

Bile consists essentially of *choleate of soda*. One use of the soda may be to neutralize the acid contained in the chyme. But the steps by which the chyme is converted into chyle and excrementitious matter are not yet understood. Doubtless the liquids secreted in the duodenum and small intestines perform the most important part of this extraordinary change. The choleic acid probably unites with the excrementitious matter, increases its consistence, and, by its stimulating qualities, induces the intestines to propel it onwards, in order to its expulsion from the body.

* *Recherches sur la Digestion*, p. 144.

There are strong reasons for believing that bile is not the only substance formed in the liver. It has been long known that, when the liver is diseased, the quantity of urea in the urine is greatly diminished. Hence it is not unlikely that urea, and perhaps even uric acid are formed in that organ. Liebig has remarked that 5 atoms protein, 15 atoms starch, 12 atoms water, and 5 atoms oxygen, may be resolved into 9 atoms choleic acid, 9 atoms urea, 3 atoms ammonia, and 60 atoms of carbonic acid. Thus,



Atoms.			Atoms.	
5 protein,	$=C^{240}H^{180}Az^{30}O^{70}$	=	9 choleic acid,	$=C^{342}H^{297}Az^{9}O^{99}$
15 starch,	$=C^{180}H^{150}O^{150}$		9 urea,	$=C^{18}H^{36}Az^{18}O^{18}$
12 water,	$=H^{12}O^{12}$		3 ammonia,	$=H^{9}Az^{3}$
5 oxygen,	$=O^{5}$		60 carbonic acid,	$=C^{60}O^{120}$
	$C^{420}H^{342}Az^{30}O^{237}$			$C^{420}H^{342}Az^{30}O^{237}$

But this does not throw much light upon the subject, as we have no evidence that starch, or any thing resembling it in composition, exists in the blood, from which the bile and urea are secreted.

Liebig affirms that none of the bile is excreted with the fæces. He conceives that it is all taken again into the system, and converted into carbonic acid and water during its circulation through the body, for the purpose of producing animal heat. The opinion is bold and ingenious. But its accuracy seems to me to be belied by the phenomena. The colour of the fæces indicates the presence of choleic acid, which may have lost its solubility in alcohol, in consequence of having entered into combination with the excrementitious matter. Were the bile absorbed into the system, it ought to be present in the blood, which is never the case except in the disease called jaundice.

The chyle formed in the lower part of the duodenum and in the other small intestines is taken up by the open mouths of the lacteals, and conveyed by them to the thoracic duct. From the difficulty, or almost the impossibility, of obtaining a sufficient quantity of chyle in a state of purity, it has hitherto been but imperfectly examined by chemists. Indeed, as in the thoracic duct, it is always mixed with *lymph*, a liquid exhaled in order to moisten and lubricate all the shut cavities of the body, from which it is taken up by the lymphatics, and conveyed to the thoracic duct, it is impossible to procure it in a state of purity except in the lacteals. Hence the quantity of pure chyle procurable can never exceed a few drops. The facts hitherto ascertained

by chemists and physiologists respecting both chyle and lymph have been detailed in a preceding chapter of this volume.

Such is the very imperfect view that can be at present given of the process of digestion. The food in the mouth is converted into a moist and comminuted mass, which in the stomach is acted on by the gastric juice, and converted into chyme. The chyme passes into the small intestines, where it is acted on by liquids, there secreted and converted into chyle and excrementitious matter. The part played by the pancreatic juice is unknown. But the soda of the bile neutralizes the acid in the chyme, while the choleic acid facilitates the evacuation of the excrementitious matter from the intestines. The chyle when completed is taken up by the lacteals, carried to the thoracic duct, where it is mixed with the lymph, and both together are conveyed to the left subclavian vein, where they mingle with the blood, and during the circulation through the blood-vessels, the conversion of the chyle into blood is completed.

CHAPTER II.

OF RESPIRATION.

The function of respiration, so essential to the existence of hot-blooded animals, and indeed of all animals, could not be understood till after the discovery of the circulation of the blood. Accordingly, there is nothing respecting this function in the writings of the Greek philosophers that is deserving of being noticed. Plato, in his Timeus, says, that, " as the heart might be easily raised to too high a temperature by hurtful irritation, the genii placed the lungs in its neighbourhood, which adhere to it and fill the cavity of the thorax, in order that their air vessels (*arteries*) might moderate the too great heat of that organ, and reduce the vessels to an exact obedience." And this opinion respecting the use of the lungs, strange as it may appear, was generally adopted by philosophers and medical men, till the chemical discoveries respecting heat made by Dr Black about the middle of the last century laid the foundation of another explanation.

The structure of the lungs seems to have been first explained

in a satisfactory manner by Malpighi, in his two epistles *De Pulmonibus*, first published in 1661. He showed that the interior portion of the lungs was composed of lobules, in the intervals between which were numerous vesicles communicating with each other, and with the branches into which the trachea is divided, and consequently always filled with air. These vesicles are lined with blood-vessels, which expose the blood from the right ventricle of the heart to the action of the air. This structure of the lungs was confirmed by the subsequent dissections of Thomas Bartholin; though he had previously held a contrary opinion.

After the structure of the lungs was ascertained, some time elapsed before anatomists were agreed about the mechanism of respiration. Swammerdam, in 1667, adopted the opinion of Des Cartes, according to whom the air is forced into the lungs by the increased density of the air around the breast, occasioned by the dilatations of the thorax, in consequence of the elevation of the ribs. This absurd theory seems to have been first refuted by Dr Walter Needham, in his celebrated work *De Formato Fœtu*, published in 1667. In 1674, it was examined and opposed at greater length by Dr Lamzweerde, a physician in Cologne. The true mechanism of respiration, the elevation of the ribs, and the action of the intercostal muscles * were pointed out. It was shown that, by the elevation of the ribs, and the depression of the diaphragm, a partial vacuum is produced in the thorax. This causes the air to be forced into the vesicles of the lungs. That organ, of consequence, is pressed against the walls of the thorax, and its cells at every inspiration are filled with air.

It has been already stated, that the almost universal opinion of physiologists was, that the use of the lungs was to cool the blood. The chyle was supposed to be converted into blood in the liver. One of the first steps towards explaining the nature of respiration was made by Dr Hooke, in his *Micrographia*, published in 1665. He gives a theory of combustion in that work, which applies very closely to the opinions entertained on the subject by modern chemists. The air, according to him, contains a small quantity of a peculiar matter, identical with a substance which exists in nitre. This substanee has the property of rapidly dissolving combustibles, and the phenomena of combustion are

* De Respiratione, p. 278.

occasioned by this rapid solution. When the substance is saturated with the combustible body, it becomes unfit for supporting combustion, and of course no combustible body will burn in it. This peculiar substance is obviously the *oxygen* of modern chemists, which is now known to constitute a fifth part of the volume of common air.

In 1664, Dr Malachi Thruston, when he took his medical degree at Cambridge, defended a thesis entitled *De Respirationis usu Primario Diatriba*, which he published three or four years afterwards.* He was of opinion that the air, or the purest portion of it, was absorbed by the blood in the lungs, and that this portion was necessary to preserve the fluidity and the heat of that liquid. The heat of the body, he says, is owing to the nitrous particles of the air absorbed by the blood, which *ferments* with the sulphureous particles. He observed that the blood acquired its scarlet colour by its union with air, and says it was with peculiar pleasure that he found that the experiments of Lower agreed with his ideas. Now Lower's work on the heart was published in 1669. Hence I think we may conclude that Thruston's *Diatriba* was not given to the public before the year 1669 or 1670.

In 1668, Dr Mayow of Oxford published his *Tracts*, which have conferred upon him so much posthumous celebrity, after he had languished in obscurity for more than a century. This work consists of five tracts. The first, *De Sal-nitro et Spiritu Nitro aerio*, in which he treats of the constitution of air, and gives a theory of combustion very similar to that of Dr Hooke. His second tract, *De Respiratione*, and his third, *De Respiratione Fœtus in Utero et Ovo*, contain his views respecting that most important function. According to him the nitro-aerial particles (that is the oxygen) of the atmosphere are absorbed by the blood in the lungs. During the circulation, they unite with the salino-sulphureous particles of the blood. This union is accompanied by fermentation, which evolves animal heat.

The dark and dusky colour of venous blood is, in his opinion, owing to the salino-sulphureous particles. Fermentation he considered as depending upon the nitro-aerial particles, and hence he inferred that the motion of the blood was owing to the same source. The chief use of respiration was, in his opinion, to keep

* It was inserted in the *Bibliotheca Anatomica* printed in 1685.

up the motion of the heart and arteries. These views he illustrated and confirmed by many ingenious experiments, in which he anticipated some of the modern discoveries respecting respiration.

Lower's work, *De Corde item de Motu et Colore Sanguinis et Chyli in eam Transitu,* was published in 1669; or a year after Mayow's tracts.* In this very ingenious treatise, he proves that the florid colour of arterial blood is owing to the absorption of air, or rather the nitrous spirit of air (oxygen) in the lungs. This nitrous spirit is dissipated during the circulation. Hence the reason of the dark colour which the blood has when it enters the right auricle and ventricle before it passes to the lungs, where it is again impregnated with air, and reassumes its florid colour.

It is well known that carbonic acid gas was obtained in a separate state by Dr Black, and that he ascertained that, when passed through lime-water, it has the property of rendering it turbid and milky. In the year 1757, by breathing through lime-water, he ascertained that the air when thrown out of the lungs contains carbonic acid.† In 1774, Dr Priestley discovered oxygen gas, and found that animals could breathe it much longer with impunity than the same bulk of common air. He found that the quality of air was deteriorated by breathing precisely as by combustion. According to him, when atmospheric air is completely deprived of phlogiston, it becomes oxygen gas; when completely saturated with phlogiston, it becomes azotic gas. Blood exposed to air acquires a florid red colour, while, at the same time, the air is deteriorated. Hence he conceived that the use of respiration was to deprive the blood of phlogiston.‡ It is curious, that, in the year 1776, he does not seem to have been aware of the formation of carbonic acid gas during respiration, though the fact had been noticed by Dr Black as early as the year 1757.

About the year 1780, Lavoisier published his experiments on

* Yet Mayow quotes Lower in confirmation of his views. My copy of Mayow is the second edition, printed (I believe, for the title-page is wanting,) in 1674; and my copy of Lower is that in the *Bibliotheca Anatomica,* printed in 1685. Doubtless additions were made to the new editions. Hence, unless we had the original editions, it would be impossible to ascertain who first struck out the ideas nearly identical stated by Thruston, Mayow, and Lower.

† Black's Lectures, ii. 87. ‡ Priestley on Air, (first series), iii. 55.

the respiration of animals.* He considered atmospherical air as a mixture of oxygen and azotic gases. He showed that, during respiration, the azotic portion of the air remained unchanged, but the oxygen portion diminished, and the portion which disappeared was replaced by carbonic acid gas. Thus he verified the fact discovered by Black, and rectified the statements of Priestley. Lavoisier considered respiration as a true combustion. In the lungs, the carbon of the blood combined with the oxygen of the air, and converted it into carbonic acid gas, just as happens when charcoal is burnt.

In the year 1788, an important treatise was published by Dr Edmond Goodwyn, entitled *On the connection of Life with Respiration*.† He endeavoured to determine the capacity of the lungs, the quantity of air which they contain, and the volume drawn in and emitted in ordinary respiration. But some of his estimates of these seem to have far exceeded the true average quantities. In the year 1790, appeared Dr Menzies's *Tentamen Inaugurale de Respiratione*, originally printed as a thesis when he graduated in Edinburgh, but afterwards, I believe, published in an English dress.‡ He endeavoured to determine the capacity of the lungs, the quantity of air drawn in and thrown out at each respiration, and the volume of oxygen gas converted into carbonic acid gas with more accuracy than had been done by Goodwyn, though I doubt whether he was successful. The latest experiments of Lavoisier and Seguin on respiration were published by Seguin in the Memoirs of the French Academy for 1789, (p. 566.)§

I shall not continue this historical detail any farther. The facts ascertained by Davy, Allen and Pepys, Prout, Berthollet, &c., will be noticed as we proceed.

The fluid respired by animals is common atmospherical air; and it has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for it. All the known gases have been tried; but they all prove fatal to the

* Mem. de l'Academie des Sciences, 1777, p. 185.

† It is said to have been written in consequence of a prize offered by the Humane Society for the best essay on the method of recovering persons apparently drowned.

‡ But I have only seen the Latin thesis printed by Menzies when he graduated at Edinburgh in 1790.

§ A posthumous volume published after the abolition of the Academy.

animal which is made to breathe them. Gaseous bodies, as far as respiration is concerned, may be divided into two classes: I. Unrespirable gases; II. Respirable gases.

I. The gases belonging to the first class are of such a nature that they cannot be drawn into the lungs of animals at all; the epiglottis closing spasmodically whenever they are applied to it. To this class belong carbonic acid, and probably all the other acid gases, as has been ascertained by the experiments of Pilatre de Rozier.* Ammoniacal gas belongs to the same class; for the lungs of animals suffocated by it were found by Pilatre not to give a green colour to vegetable blues.†

II. The gases belonging to the second class may be drawn into the lungs, and thrown out again without any opposition from the respiratory organs; of course the animal is capable of respiring them. They may be divided into four subordinate classes; 1. The first set of gases occasion death immediately, but produce no visible change in the blood. They occasion the animal's death merely by depriving him of air, in the same way as he would be suffocated by being kept under water. The only gases which belong to this class are *hydrogen* and *azotic*. 2. The second set of gases occasion death immediately, but at the same time they produce certain changes in the blood, and therefore kill not merely by depriving the animal of air, but by certain specific properties. The gases belonging to this class are *carburetted hydrogen, sulphuretted hydrogen,*‡ *carbonic oxide,* and perhaps also *nitrous gas.* 3. The third set of gases may be

* Jour. de Phys. xxviii. 418. Pilatre de Rozier went into a brewer's tub while full of carbonic acid gas evolved by fermentation. A gentle heat manifested itself in all parts of his body, and occasioned a sensible perspiration. A slight itching sensation constrained him frequently to shut his eyes. When he attempted to breathe, a violent feeling of suffocation prevented him. He sought for the steps to get out; but not finding them readily, the necessity of breathing increased, he became giddy, and felt a tingling sensation in his ears. As soon as his mouth reached the air he breathed freely, but for some time he could not distinguish objects; his face was purple, his limbs weak, and he understood with difficulty what was said to him. But these symptoms soon left him. He repeated the experiment often; and always found, that, as long as he continued without breathing, he could speak and move about without inconvenience; but whenever he attempted to breathe, the feeling of suffocation came on. Ibid. p. 422.

† Jour. de Phys. xxviii. p. 424.

‡ See Chausier's experiments, ibid. lvi. p. 35.

breathed for some time without destroying the animal, but death ensues at last, provided their action be long enough continued. To this class belong the nitrous oxide and oxygen gas.* 4. The fourth set may be breathed any length of time without injuring the animal. *Air* is the only gaseous body belonging to this class.

Let us now endeavour to state the phenomena of respiration with as much precision as possible:

1. From the experiments of Messrs Allen and Pepys, it appears that the lungs of a stout man about five feet ten inches high, after a full expiration, still retain 108 cubic inches of air.† The previous determination of Goodwyn very nearly agrees with this. He reckoned the air in the lungs after an expiration, to be 109 cubic inches.‡

In order to discover the capacity of the lungs, I made twelve individuals, young men from fourteen to thirty-three years of age, make a full inspiration and then expel from the lungs as much air as they could. The following table exhibits the results:

1.	100 cubic inches.
2.	140
3.	163
4.	180
5.	193
6.	200
7.	200
8.	200
9.	200
10.	200
11.	210
12.	250§

The individual who could expel only 100 cubic inches of air

* Perhaps also nitrous gas might have the same effect, if it could be breathed by an animal whose lungs contained no oxygen.

† Phil. Trans. 1809, p. 410. ‡ Goodwyn on Respiration, p. 27.

§ Mr Thackrah mentions a tall young cornet who was able to throw out 10¼ pints of air from his lungs. If he means *wine pints*, as is likely, the quantity thus thrown out was 296 cubic inches. See Thackrah *on the effects of different arts, trades, and professions on health*, p. 16. He reckons the average in adults to be 219 cubic inches. He says that the capacity of the female chest is less than that of the male, which he ascribes to the wearing of tight stays. The mean quantity of air thrown out of the chest of ten females aged 18½, and in good health, by a forced expiration, was 3½ pints, or only 101 cubic inches. Ibid. p. 96.

from the lungs after a full inspiration, was a girl about fifteen years of age: The two who expelled 140 and 163 were my two sons, the first aged fourteen, the second aged twelve. The individual who expelled only 180 cubic inches was a very thin spare gentleman aged twenty-one. I myself could only expel 193 cubic inches from the lungs after a full inspiration. These experiments were often repeated with the same individual, and the quantity of air which he was able to expel from the lungs after a full inspiration was always the same. The mean of the whole is 186⅓ cubic inches, or if we leave out the girl, who only made one trial, as the quantity expelled was so small, the average will be 194 cubic inches; or very nearly the quantity, which I myself was able to expel from the lungs by a forced expiration after a full inspiration. If to this we add the 108 cubic inches which Allen and Pepys found to remain in the lungs after the full expiration which accompanies death, the quantity of air which the lungs are capable of containing, will be 302 cubic inches.

The quantity of air employed in respiration during a given time will of course depend upon the number of inspirations and expirations per minute. Now these differ considerably in different individuals. Dr Hales reckons them at twenty in a minute. A man on whom Dr Menzies made experiments, breathed only fourteen times in a minute. Sir H. Davy informs us that he made between 26 and 27 in a minute. I myself make about 19 at an average. The average of all is 20. Now 20 in a minute make 28,800 in 24 hours.

There is a great diversity in the statements of different experimenters respecting the quantity of air which an ordinary sized man draws into the lungs at a single inspiration, and again expels by an ordinary expiration. Dr Menzies concluded from the mean of 56 trials that the quantity of air drawn into the lungs at each inspiration is about forty cubic inches. And Dr Jurin had long before estimated the quantity at forty cubic inches. The experiments of Allen and Pepys, made with great care and upon a large scale, give the quantity only 16½ cubic inches. Dr Goodwyn reckons it from his own experiments at fourteen cubic inches.* Borelli had previously estimated it at eighteen or twenty cubic inches.† I tried the quantity of air which I myself drew in-

* Goodwyn on Respiration, p. 34. † As quoted by Menzies in his Thesis.

to my lungs by an ordinary inspiration. The mean of a great many trials, made with as much care as possible, gave sixteen cubic inches. I caused a tall and stout man with an expanded chest to accustom himself to breathe through a tube without any effort. The quantity which he expelled at a single expiration was also sixteen cubic inches. From these trials, corroborated as they are by the experiments of Allen and Pepys, I am disposed to conclude that the quantity of air drawn into the lungs at each inspiration is sixteen cubic inches, or about $\frac{1}{19}$th of the whole air that the lungs are capable of containing. Now, as the number of inspirations in 24 hours is 28,800, it is clear that the volume of air taken into the lungs in 24 hours averages 240,800 cubic inches, or 266$\frac{2}{3}$ cubic feet, or 10$\frac{2}{3}$ avoirdupois lbs. weight of air.

2. There is a great diversity in the opinion of different experimenters respecting the ratio which subsists between the volume of air inspired, and that which is expired. According to Davy, air, by a single inspiration and expiration, is diminished from $\frac{1}{70}$th to $\frac{1}{100}$th part of its bulk.* In the numerous and accurate experiments made by Allen and Pepys on a very large scale, the average diminution was little more than half a per cent., and even this seems to have been owing rather to unavoidable inaccuracy than to real absorption. In the experiments of Berthollet, conducted also with very great care, the diminution varied from 0·69 to 3·70 per cent.† I made many years ago numerous experiments by enclosing animals in a large glass receiver, through which a gentle current of atmospherical air was constantly passing. On making the requisite allowance for the absorption of a little carbonic acid gas by the water in the vessels through which the air passed, I found that there was no diminution whatever in the volume of air by passing it through the lungs. But the case was very different when an animal was confined in a bell glass, and obliged to breathe the same air for a long time. The volume was always diminished, and the diminution always increased as the quantity of air which the animal breathed was diminished. In one case a rabbit was made to breathe a very small quantity of air. The animal died almost immediately; but the volume of the air was reduced to one-third of its original bulk. From these experiments it may, I think, be concluded that in ordinary

* Davy's Researches, p 431. † Mem. d'Arcueil, ii. 461.

respiration the air drawn into the lungs is nearly balanced by the air thrown out. But when the animal is placed in untoward circumstances, and is obliged to make forced inspirations, the bulk of the air is diminished, and this diminution is inversely as the volume of the air which the animal is obliged to breathe.

3. It is well-known that atmospherical air (abstracting a little vapour of water and a trace of carbonic acid gas) is composed of eighty volumes azotic and twenty volumes oxygen gas. But when it is thrown out of the lungs by expirations, the volume of oxygen gas is diminished, being replaced by exactly the same bulk of carbonic acid gas. Various experiments have been made to ascertain how much of this principle is lost by respiration in a given time; but they by no means correspond with one another. Indeed, it is extremely probable, if not absolutely certain, that the degree of effect which the same animal produces upon the air respired differs materially at different times, and in consequence of different circumstances. Nothing, therefore, beyond an approximation can be expected from our experiments on this function.

Dr Menzies was the first who attempted to ascertain the quantity of oxygen consumed by a man in a day. According to him, 36 inches are consumed in a minute, and of course 51,840 inches in twenty-four hours.* This estimate exceeds that obtained by Lavoisier and Davy from their experiments. Lavoisier and Seguin estimate the quantity of oxygen consumed by a man in twenty-four hours at 46,037 cubic inches, and this nearly coincides with the results which Lavoisier obtained from his last experiments, on which he was occupied when he was dragged to the place of execution. With this also the experiments of Davy coincide very well. He calculates that 31·6 inches of oxygen are consumed in a minute, which, in twenty-four hours, make 45,504 inches.†

But these determinations can be considered only as approximations. Upon examining the air expired from my own lungs, I found that the volume of carbonic acid gas which it contained differed considerably from day to day. In the month of May 1832, I analyzed air from my own lungs on ten consecutive days, between eleven and twelve o'clock each day. The following table exhibits the result:‡

* Bostock on Respiration, p. 81.

† Davy's Researches, p. 433.

‡ Records of General Science, i. p. 28.

	Carbonic acid gas.
1st day,	4·64 per cent.
2d	4·70
3d	6·07
4th	3·27
5th,	5·26
6th	2·05
7th	2·39
8th	3·85
9th	3·05
10th	7·16

The volume of carbonic acid gas, and, consequently, the consumption of oxygen gas on the tenth day, was three and a-half times greater than on the sixth day. The mean of the whole was 4·24 per cent. I made ten gentlemen, who were at that time operative chemists in my laboratory, breathe into a glass tube filled with mercury, and analyzed each portion of air thus obtained. The trials were made about eleven o'clock of the day. The results were as follows:

	Carbonic acid gas.
Mr Thomas Thomson, (aged 14),	3·06 per cent.
Ditto, next day,	3·61
Mr J. Colquhoun, (aged 18),	3·09
Mr Forrest, (aged 18),	2·10
Ditto, next day,	5·19
Mr Coverdale, (aged 18),	2·54
Ditto, next day,	1·71
Mr Cargill, (aged about 30),	4·68
Mr Bruce, (aged about 20)	5·46
Dr Duncan, (aged about 21),	6·17
Dr Short, (aged about 40),	6·85
Mr Frazer, (aged about 30)	7·08

Two ladies allowed me to examine the air from their lungs. The result was as follows:

	Carbonic acid gas.
First lady,	2·85 per cent.
Second lady,	4·06

The diversity in the volume of carbonic acid gas, and consequently of the quantity of oxygen gas consumed by respiration, is fully as great as in my own case. The average of the whole

is 4·16 per cent. of carbonic acid gas in the air expired from the lungs. Now, this does not differ much from 4·24, the average in my own case of ten days at eleven o'clock. I am disposed, therefore, to consider 4·24 per cent. as the average volume of oxygen gas converted into carbonic acid gas at eleven o'clock, or rather between eleven and twelve in the forenoon.

4. Dr Prout has shown by a number of well-conducted experiments on himself, that the proportion of carbonic acid formed at each inspiration is different at different periods of the day. It is at its maximum nearly about noon, and is at its minimum about midnight. It appears farther from his trials that the quantity of carbonic acid gas in expired air begins to increase nearly at twilight. The following table exhibits the proportion per cent. of carbonic acid in the air expired from his lungs during every hour of the day. The experiments from which it was deduced were made in August:*

Hour A. M.	Carbonic acid per cent.	Hour P. M.	Carbonic acid per cent.
6	3·43	6	3·40
7	3·48	7	3·35
8	3·56	8	3·32
9	3·66	9	3·30
10	3·78	10	3·30
11	3·92	11	3·30
12	4·10	12	3·30
1	3·98	1	3·30
2	3·80	2	3·30
3	3·65	3	3·30
4	3·54	4	3·33
5	3·46	5	3·38
		Mean,	3·45

Dr Prout found that alcohol and all fermented liquors diminished the proportion of carbonic acid formed by respiration, and this was confirmed by the experiments of Dr A. Fyfe. They found likewise that when the constitution is affected by mercury, the proportion of carbonic acid gas in the air expired is diminished. Dr Fyfe found that the quantity was likewise diminished by a course of nitric acid, and by a vegetable diet.† Mr Macgregor

* Annals of Philosophy, ii. 328, and iv. 321. † Ibid. iv. 334.

ascertained that the air expired by persons ill of confluent small-pox contained as much as eight per cent. of carbonic acid gas. During the eruptive fever of measles it amounted to from four to five per cent. In proportion as health was resumed, the per centage diminished. In chronic skin diseases, an augmentation was also observed, and in one case of ichthyosis the mean per centage was 7·2. In diabetes, no aberration could be detected.*

A set of experiments upon the same subject has been published by Mr Coathupe† in 1839. His apparatus was simple and excellent, and the experiments appear to have been conducted with great care. They were continued for a week. The following is the result obtained:

		Carbonic acid per cent. of air exposed.
From 8 o'clock A. M.	to 9½	4·37
10 ...	to 12	3·90
12 noon,	to 1	3·92
2 P. M.	to 5½	4·17
7 P. M.	to 8½	3·63
9 P. M.	to midnight,	4·12
	Mean,	4·02

These experiments do not agree with Dr Prout's, and show the necessity of repeating them upon many individuals before any general conclusions can be drawn.

From the experiments of Prout, it appears that the quantity of carbonic acid gas produced by respiration is at its maximum at noon, and that its quantity at 11 A. M. is to the mean quantity for twenty-four hours as 3·92 to 3·45. Hence it follows that the mean volume of carbonic acid gas in 100 volumes of air expired, deduced from the preceding experiments, is 3·72.

From the experiments of Boussingault, it would appear that a cow in twenty-four hours discharges by the lungs about five times as much carbon as a man does.‡ A horse discharges about six times as much.

Now, if the preceding estimate of the quantity of air drawn

* Atheneum, No. 677, p. 822. † Phil. Mag. (3d series), xiv. 401.

‡ Ann. de Chim. et de Phys. lxxi. 126.

into the lungs at each inspiration be accurate, it will follow, that in twenty-four hours 8957·76 cubic inches of oxygen gas are converted into carbonic acid gas by the respiration of every adult, but 8957·76 cubic inches of carbonic acid weigh 4234 grains, and contain 1155 grains, or very nearly one-sixth of a pound avoirdupois, or two ounces and two-thirds of carbon. This, then, is the amount of carbon discharged every twenty-four hours from the body by means of the lungs."

If we reckon the quantity of blood in the body of an adult twenty-six pounds, and that dry blood amounts to twenty per cent. of liquid blood, it is obvious that, if the carbonic acid were derived from the carbon of blood (constituting 51·96 of dry blood,) the whole carbon would be consumed in little more than sixteen days.

5. The general opinion at present entertained is, that the volume of oxygen gas which disappears is greater than that of the carbonic acid gas, which replaces it. If, as is most probable, the oxygen gas is absorbed by the blood in the lungs, and combining with carbon during the circulation, and is evolved in the state of carbonic acid gas when the blood passes next through the lungs, it is at least possible that a portion of the oxygen gas absorbed may combine with hydrogen during the circulation and form water. The experiments of Despretz, which will be stated afterwards, lead to the conclusion that about $\frac{1}{10}$th of the oxygen gas absorbed combines with hydrogen and forms water, and that $\frac{9}{10}$ths of it go to the formation of carbonic acid gas. If this estimate be true we must, in order to get the true volume of oxygen gas abstracted from air during respiration, augment the volume of carbonic acid gas evolved by $\frac{1}{10}$th. This would make the average quantity of oxygen abstracted from the air inspired amount to 4·092 per cent.

When venous blood passes through the lungs it becomes arterial blood, distinguished by its bright scarlet colour. Now, as the colouring matter of blood is the red globules, it is obvious that they must be the portion of the blood which has absorbed oxygen. The blood continues arterial till it passes through the capillary vessels. Here it loses its scarlet colour and becomes venous blood. In the capillaries, therefore, the oxygen which has combined with the globules must be converted into carbonic

acid. Liebig conceives that it is the iron in the globules which combines with the oxygen. It thus becomes peroxide. In the capillaries the half atom of oxygen with which it had united unites with carbon, and is converted into carbonic acid. This carbonic acid combines with the protoxide of iron. In the lungs the carbonic acid is displaced by the oxygen of the atmosphere, and passes into the air, while an equal volume of oxygen gas unites with the protoxide, and converts it into red oxide. This explanation is certainly very ingenious.

6. The air when emitted from the lungs has probably the temperature of that organ, or is heated to about 98°. It is loaded with moisture at that temperature. Now the force of the vapour of water at 98° is 1·74 inch. Hence it follows that the air expired from the lungs contains rather more than $\frac{1}{17}$th of its volume of vapour, or every 100 cubic inches of air expired will contain 5·9 cubic inches of vapour. But the specific gravity of vapour at 98° is 0·0362, that of air being 1. This is nearly $\frac{1}{28}$th part of the weight of the same volume of air. Hence the weight of the aqueous vapour in every 100 cubic inches of air expired is about 1·8 grain. This in 24 hours will amount to 4334 grains, or somewhat more than 9 avoirdupois ounces. Such is the quantity of moisture given out daily from the lungs of an adult person.

MM. Henri and Chevalier collected a quantity of the matter of expiration of cows which had condensed on the ventilators of a cow-house in Paris. It was a colourless liquid having an ammoniacal smell. It contained no salt of lime, potash or soda, but only salts of ammonia. These salts were,

Lactate
Carbonate
Acetate
Hippurate } of ammonia.

Also a balsamic volatile body from the dung of the cattle in the stable. It is more than probable that the ammonia and the acids combined owed their origin to the dung or urine of the cattle rather than to what was expired from the lungs.*

7. The opinion at present entertained respecting the effect of respiration upon the azotic constituent of the air is not very decided. Some suppose that the azote of the air is not affected by

* Jour. de Pharm. xxv. 421.

respiration, others affirm that a portion of it is absorbed as well as of the oxygen. While a third party, and that by far the most numerous, conceive that a portion of azotic gas is emitted from the blood in the lungs; that this portion just balances the portion of oxygen which has combined with hydrogen, and thus prevents any diminution in the bulk of the air from becoming sensible.

If we adopt the view of Dr Priestley and Professor Liebig, that a great deal of air is carried to the stomach by the saliva, and that this air makes its way into the blood, and that its azotic portion is emitted in the lungs in a gaseous form, we see a source for the origin of the azotic gas that may be evolved in the lungs.

It is obvious that the 108 cubic inches of air remaining in the lungs after a full expiration, must contain less than the normal quantity of oxygen. Hence, even admitting that the azote of the air is not affected by respiration, still the air expired would appear to contain an excess of azote, or a greater bulk than exists in common air. I think it not unlikely that this may be the reason of the apparent increase of azotic gas in the air expired.

8. It is most probable that the blood, as it passes through the lungs, absorbs oxygen from the air inspired; and that, during the circulation of the blood through the capillary vessels, this oxygen is converted partly into carbonic acid and partly into water. Tiedemann and Gmelin suppose that this carbonic acid combines with the soda of the blood, and is displaced during the circulation by lactic acid, while the lactate of soda is decomposed in its turn by urea. This hypothesis, or something very like it, has been embraced by Dumas. But Liebig's explanation given above is more plausible. We do not know enough respecting the normal state of the constituents of blood, consisting chiefly of albumen and cruorin, to be able to point out the change effected by this abstraction of carbon and hydrogen.* But there is reason

* MM. Macaire and Marcet analyzed dried arterial and venous blood, and ound that venous blood contained more carbon and less oxygen than arterial blood.

	Dried arterial blood.	Dried venous.
Carbon, .	50·2	55·7
Azote, .	16·3	16·2
Hydrogen, .	6·6	6·4
Oxygen, .	26·3	21·7
	99·4	100·0

See Mem. de la Societé de Phys. et d'Hist. Nat. de Geneve, v. 223.

to believe that the oxygen absorbed by the blood in the lungs is the cause why it acts as a stimulus to the heart, and makes it to contract. For the action of the heart, and consequently the circulation of the blood, immediately ceases when respiration is prevented. This is doubtless the reason why respiration is so essential to life, that when it is suspended for even a very short time, death ensues.

A great number of experiments have been made on the respiration of fishes by Provençal and Humboldt.* It is well known that these animals require oxygen gas as well as other animals, and that if the water in which they are be deprived of the whole of its air, they die very speedily. Provençal and Humboldt employed for their experiments the waters of the Seine. They separated the air from a quantity of it by boiling, and subjected it to a chemical analysis. Into another quantity of the same water, tenches were put and confined for several hours till they began to suffer; they were then withdrawn, and the air separated from the water in which they had lived, and subjected to chemical analysis. In every case a portion, both of oxygen and azote had disappeared, and a quantity of carbonic acid had been formed. The following table exhibits the results of a variety of their experiments:

Nature of the gases.	Gases before experiment.	Ditto after ditto.	Difference.	The fishes have Absorbed.	The fishes have Produced.	Azote absorbed, the oxygen being 100.	Carb. acid produced, the oxygen absorbed being 100.	No of fishes and time.
Total,	175·0	135·1	39·9	—	—	—	—	Three tenches during 5 h. 15 minutes.
Oxygen,	52·1	5·6	—	46·5	—	—	—	
Azote,	115·9	95·8	—	20·1	—	43	57	
Carbonic ac.	7·0	33·7	—	—	26·7	—	—	
Total,	524·0	404·0	119·6	—	—	—	—	Seven tenches during 6 h.
Oxygen,	155·9	44·0	—	111·9	—	—	—	
Azote,	347·1	249·5	—	97·6	—	87	80	
Carbonic ac.	21·0	110·9	—	—	89·9	—	—	
Total,	524 0	453·0	71·0	—	—	—	—	Seven tenches during 5h
Oxygen,	155·9	10·5	—	145·4	—	—	—	
Azote,	347·1	289·5	--	57·6	—	40	91	
Carbonic ac.	21·0	153·0	—	—	132·0	—	—	

* Mem. d'Arcueil, ii. 259.

Nature of the gases.	Gases before experiment.	Ditto after ditto.	Difference.	The fishes have Absorbed.	Produced.	Azote absorbed, the oxygen being 100.	Carb. acid produced, the oxygen absorbed being 100.	No. of fishes and time.
Total,	483·0	345·5	137·5	—	—	—	—	One tench during 17 hours.
Oxygen,	143·7	4·2	—	139·5	—	—	—	
Azote,	320·0	294·1	—	25·9	—	19	—	
Carbonic ac.	19·3	47·2	—	—	27·9	—	20	
Total,	483·0	408·0	75·0	—	—	—	—	Three tenches during 7½ hours.
Oxygen,	143·7	62·6	—	81·1	—	—	—	
Azote,	320·0	285·4	—	34·6	—	43	—	
Carbonic ac.	19·3	60·0	—	—	40·7	—	50	
Total,	483·0	398·6	84·4	—	—	—	—	Three tenches during 5 hours.
Oxygen,	143·7	40·0	—	103·7	—	—	—	
Azote,	320·0	246·6	—	73·4	—	11	—	
Carbonic ac.	19·3	112·0	—	—	92·7	—	89	
Total,	483·0	372·5	110·5	—	—	—	—	Two tenches during 7 h.*
Oxygen,	143·7	37·8	—	105·9	—	—	—	
Azote,	320·0	252·9	—	67·1	—	63	—	
Carbonic ac.	19·3	81·8	—	—	62·5	—	59	

The quantity of gas obtained from the Seine water was, at an average, 0·0275 of its bulk, or not quite $\frac{1}{36}$th part; the average quantity of oxygen which this gas contained was 0·310.

From these experiments it appears, that the respiration of fishes differs very much from that of other animals. The oxygen is not merely converted into carbonic acid, as happens during the respiration of men and the larger animals; but a portion of it is absorbed and introduced into the system. A portion also of azote is absorbed. The quantity of air consumed by fishes is extremely small, when compared with that consumed by terrestrial animals. This will appear from the following table, in which the bulk of the air consumed, and of the carbonic acid formed in an hour, is stated in cubic inches:

Time.	Oxygen in air after the expert.	No. of fish.*	Hours the expert. lasted.	Absorption in 1 hour in cubic inches. Oxygen.	Azote.	Carb. ac. produced, in cub. in.
28 Feb.	0·056	3	5¼	0·0245	0·0106	0 0140
3 March,	0·151	7	6	0·0221	0·0192	0·0177
7 March,	0·034	7	8½	—	—	0·0185
11 March,	0·017	1	17	0·0679	0·0126	0·0136
28 Feb.	0·178	3	7½	0·0298	0·0123	0·0150
24 Feb.	0·141	3	5	0·0575	0 0405	0·0512
20 Feb.	0·130	2	7	0·0635	0·0397	0·0370

* The numbers in this table indicate cubic centimetres. A cubic centimetre is equal to 0·0610 of a cubic inch.

From this table, compared with the facts stated in the preceding part of this section, it follows, that in a given time a man consumes 50,000 times as much oxygen gas as a tench. Yet the presence of this principle is equally necessary for the existence of both.

The experiments of M. Nysten on the effect of injecting oxygen gas into the veins of living animals, made in 1811, show that blood readily absorbs this gas. It would be an important fact if it could be ascertained whether injections of oxygen gas into the veins of living animals could be so far substituted for respiration as to prolong the life of the animal. It would be difficult, however, to make such an experiment in an unexceptionable manner. Were as much oxygen gas as the blood would readily absorb injected into the veins of an animal, and were the animal, together with another in its natural state, plunged into a vessel filled with hydrogen gas, it might perhaps be ascertained whether the former would live longer than the latter.

An interesting set of experiments, which throws considerable light on respiration, was made by M. Boussingault in 1839.* A cow giving milk was fed with a quantity of food carefully weighed out for three days, and the quantity of milk, fæces, and urine emitted during that time was also determined. The food per day was,

Potatoes, . .	32·418	lbs. avoirdupois.
Hay (2d crop) .	16·535	
Water, . .	132·282	

It was necessary to determine how much water the food contained. It was found to be as follows:

	Dry.		Water.
The potatoes consisted of,	9·08 lbs.	+	23·368 lbs.
The hay of, . .	14·22	+	2·315
	23·30		25·683
Water, . . .			132·282
			157·965

So that the dry portion of the food was 23·3 lbs., and the water 157·965 lbs.

The weight of the milk, urine, and fæces was as follows:—

* Ann. de Chim. et de Phys. lxxi. 113 and 128.

			Dry.		Water.
Milk,	18·7 lbs.	composed of	2·54 lbs.	+	16·16
Urine,	18·13		2·12	+	16·01
Fæces,	62·63		8·819	+	54·81
		Total,	13·479		86·98

Specific gravity of milk, . . . 1·035
Specific gravity of urine, . . . 1·034

All of these dry substances were subjected to an ultimate analysis, and found composed as follows:—

	Potatoes. lbs.	Hay. lbs.	Milk. lbs.	Urine. lbs.	Fæces lbs.	Total food.	Total in dejecs.
Carbon,	4·004	6·698	1·387	0·578	3·774	10·702	5·739
Hydrogen,	0·527	0·796	0·218	0·055	0·458	1·323	0·731
Azote,	0·109	0·341	0·102	0·080	0·203	0·450	0·385
Oxygen,	3·986	4·963	0·709	0 549	3·325	8·949	4·583
Salts and earth,	0·454	1·422	0·124	0·849	1·058		
	9·08	14·22	2·54	2·111	8·818		

The cow neither gained nor lost in weight during the experiment. The carbon taken in exceeded that in the dejections by nearly 5 lbs. Therefore 5 lbs. of carbon must have been discharged by respiration and transpiration. The hydrogen taken in exceeded that in the dejections by nearly half a pound, which must have been thrown out in the form of water by respiration or transpiration. The difference in the quantity of azote taken in and given out is so small that it may be only an error in the experiment. But, as the quantity taken in is rather greater than that given out, we have no reason to conclude that azote is absorbed by the lungs.

Boussingault made a similar experiment on a horse for three days, during which he neither gained nor lost weight. The food per day was,

Hay, . . 16·54 lbs.
Oats, . . 4·87
Water, . . 266·11

The dejections per day were,

Urine, . . 2·928 lbs. sp. gr. 1·064
Fæces, . . 3·45

The composition of food and dejections,

	Dry.		Water.
Hay, . .	14·26 lbs.	+	2·28 lbs.
Oats, . .	4·14	+	0·73
Dry food,	18·40		266·11
Water, . .			269·12

	Dry.		Water.
Urine, . .	0·339 lbs.	+	2·589 lbs.
Fæces, . .	7·78	+	23·67
	8·119		26·259

The ultimate analysis gave,

	Hay. lbs.	Oats. lbs.	Urine. lbs.	Fæces. lbs.	Total food.	Total dejections.
Carbon, . .	6·531	2·099	0·121	3·001	8·630	3·122
Hydrogen, .	0·713	0·265	0·013	0·397	0·798	0·410
Azote, .	0·214	0·091	0·042	0·171	0·305	0·213
Oxygen, .	5·518	1·519	0·038	2·933	7·037	2·971
Ashes, .	1·283	0·166	0·123	1·268	1·449	1·391
	14·259	4·140	0·337	7·77	18·219	8·107

The very same inferences may be drawn from this experiment as from that of the cow. A good deal of the carbon and hydrogen must escape by the lungs and skin. The azote thrown out is rather less than that in the food, but the difference is so small that it may be owing to errors in the experiment. The water taken into the stomach of the

Cow, . .	157·965 lbs.	Given out 36·98 lbs.
Horse, . .	266·11	26·259

Hence, in twenty-four hours the quantity of water given out by respiration and transpiration must have been in the

Cow, . . . 120·985 lbs.
Horse, . . 239·86

This is a much greater quantity than we were prepared to expect.

Dr Goodwyn has shown very clearly that black blood does not stimulate the heart to contract; but that red blood does.*

The blood is a fluid of so complex a nature that it is not easy to ascertain the changes produced in it by exposure to different gases out of the body; and even if that could be done, we have

* See the fourth section of his work on the *Connection of Life with Respiration*.

no method of proving that the effects of these gaseous bodies upon the coagulated blood are the same as they would be on the blood in its natural state, circulating in the vessels of a living animal. The facts which have been ascertained are the following:

1*st.* It appears from the experiments of Priestley, Girtanner, and Hassenfratz, that when venous blood is exposed to oxygen gas confined over it, the blood instantly assumes a scarlet colour. Davy could not perceive any sensible diminution of the bulk of the gas.

2*d.* The same change of colour takes place when blood is exposed to common air. In this case a quantity of carbonic acid gas is formed, and a quantity of oxygen gas, exactly equal to it in bulk, disappears; making allowance for the small quantity of carbonic acid, which we may suppose to be absorbed by the blood itself.

3*d.* Venous blood exposed to the action of azotic gas continues unaltered in colour; neither does any perceptible diminution of the gas ensue.

4*th.* Venous blood exposed to the action of nitrous gas becomes of a deep purple, and about one-eighth of the gas is absorbed.

5*th.* Venous blood exposed to nitrous oxide becomes of a brighter purple, especially on the surface, and a considerable portion of the gas is absorbed.

6*th.* Venous blood exposed to carbonic acid gas becomes of a brownish-red colour, much darker than usual, and the gas is slightly diminished in bulk.

7*th.* Carburetted hydrogen gas gives venous blood a fine red colour, a shade darker than oxygen gas does, as was first observed by Dr Beddoes, and at the same time a small portion of the gas is absorbed. This gas has the property of preventing, or at least greatly retarding the putrefaction of blood, as was first observed by Mr Watt.*

8*th.* When arterial blood is put in contact with azotic gas, or carbonic acid gas, it gradually assumes the dark colour of venous blood, as Dr Priestley found.† The same philosopher also observed, that arterial blood acquired the colour of venous blood when placed *in vacuo*.‡ Consequently this alteration of colour

* Davy's Researches, p. 380. † Priestley, iii. 363.

‡ Priestley, iii. 363, and Ann. de Chim. ix. 269.

is owing to some change which takes place in the blood itself, independent of any external agent.

The arterial blood becomes much more rapidly and deeply dark coloured when it is left in contact with hydrogen gas placed above it.* We must suppose, therefore, that the presence of this gas accelerates and increases the change, which would have taken place upon the blood without any external agent.

9th. If arterial blood be left in contact with oxygen gas, it gradually assumes the same dark colour which it would have acquired *in vacuo*, or in contact with hydrogen; and after this change oxygen can no longer restore its scarlet colour.† Therefore it is only upon a part of the blood that the oxygen acts; and after this part has undergone the change which occasions the dark colour, the blood loses the power of being affected by oxygen

10th. Mr Hassenfratz poured into venous blood a quantity of chlorine; the blood was instantly decomposed, and assumed a deep and almost black colour. When he poured common muriatic acid into blood, the colour was not altered.‡

11th. But one of the great purposes which respiration serves is the evolution of *heat*. The *temperature* of all animals depends upon it. It has been long known that those animals which do not breathe have a temperature but very little superior to the medium in which they live. This is the case with fishes and many insects. Man, on the contrary, and quadrupeds, which breathe, have a temperature considerably higher than the atmosphere: that of man is 98°. Birds, which breathe in proportion a still greater quantity of air than man, have a temperature equal to 103° or 104°.

Before attempting to give a theory of animal heat, it may be worth while to state the most important facts that have been ascertained respecting the temperature of man and the inferior animals.

The internal temperature of an adult man in a temperate climate is about 98°. When he passes from a cold to a hot climate his temperature rises to 98½° or even to 101°. In general the heat under the tongue is 98°, and that in the arm-pit 97° or 96½°. But Deluc assures us that, if a thermometer be kept an hour in the arm-pit, it rises to 98°. There seems no difference in the mean temperature of the different races of men.

* Fourcroy, Ibid. vii. p. 149. † Ibid. ix. p. 268. ‡ Ibid.

The human body does not seem capable of bearing exposure to a cold of 17°.5, unless counteracted by active motion, without losing the sensibility and the life of the part thus exposed. Nor can it bear long exposure to a heat of 97°, without pernicious effects. Lemonnier staid half an hour each day for twenty-eight days in a bath, heated to 100° without inconvenience. He then went into a bath of 112°. In six minutes sweat ran down his face, and his body was red and swelled. After seven minutes he was in a violent agitation, the pulse quick and strong, and during the eighth minute he was attacked by giddiness, which obliged him to come out of the bath.* Dr Berger could bear a bath of 108° only for ten minutes. His pulse rose from 80 to 112. Berger and Delaroche suffered little from ten minutes continuance in a dry stove heated to 175°, and from thirteen minutes continuance in a vapour bath of 102½°.†

The experiments of Dr Fordyce, Dr Blagden, Sir Joseph Banks, &c. in 1775 are well-known. They went into a room heated to 260°, and staid in it for a considerable time without inconvenience. From some of their experiments, particularly those of Dr Fordyce, in which the room was heated by the vapour of water, it would seem to follow that the human body in certain circumstances, has the power of generating cold.‡

The heat of new-born children is higher than that of adults, being 98°.5 or 99°. According to the observations of John Hunter the heat, when we are asleep, is less than when we are awake.

Dr John Davy made a set of observations on the temperature of various parts of his body in the morning when coming out of bed, which it may be worth while to state:

Middle of the sole of the foot,	90°
Heel under the *tendo Achillis*,	93
Shin bone,	91½
Calf of the leg,	93
Ham,	95
Above the artery of the thigh,	94
Middle of the rectus muscle of the thigh,	91
Groin,	96·5
Quarter of an inch above the navel,	95
Above the 6th left rib,	94
Above the 6th right rib,	93

* Berger; Memoires de la Societé de Physique et d'Hist. Naturelle de Geneve, vi. p. 320.

† Ibid. p. 326.

‡ Phil. Trans. 1785, pp. 111, 484.

Dr Davy ascertained also that arterial blood in a healthy animal is 1° or 1°.5 hotter than venous blood.

The following observations were made on a female:

Heat in the female bladder,	. .	101½°
...	vagina, . .	101
...	rectum, ...	100½
...	mouth, . .	99
...	arm-pit, . . .	97·61

According to Dr Berger, when an animal is in a dormant state, it loses three-fourths of its natural heat, reckoning from 32°. * In asphyxia, syncope, gangrene, and sphacelus, the heat of the body diminishes. During a pleurisy in Minorca the heat of the patient was from 102° to 104°.† A soldier at Colchester, while ill of the Walcheren intermittent fever, had his skin of the temperature 102°. But after the affusion of cold water it sunk to 97°. The headach disappeared, and a gentle moisture came out on the skin.‡ In intermittents, according to Schwenkie, the heat of the skin varies from 100° to 108°,§ while De Haen states the heat in continued fevers to be as high as 109°.|| Dr Currie states from his own observations that in scarlatina the heat of the skin varies from 106° to 112°.¶ While, according to Chisholm, it varies in inflammatory fever from 99° to 112°.** Dr Berger states the heat of an abscess in the thigh at 100°††

Such are the most important facts which have been ascertained respecting the heat of the human body in health and disease. I shall now state the temperatures of various inferior animals, as they have been collected by the industry of Dr Berger.‡‡

Apes.

Simia Aygula (arm-pit), 104°.5 and 101°. John Davy.
Callitriche (rectum), 96°.

Carnivorous Quadrupeds.

Mean heat of these animals, 103°.25.
Cat, 101° to 102°. Pulse, 100.
Panther, 102°.
Young tiger, 99°.
Jackal, 101°.
Bat, 100° to 101°.
Viverra *Monzos*, 103°.
Dog aged three months, 103°.064.§§
An adult male cat, 103°.604.||||

Gnawers.

Mean heat, 102°.4.
Rabbit, 99°.5.

* Memoires de la Societé de Physique, et d'Hist. Nat. de Geneve, vii. 310.
† Edin. Essays, ii. Art. 29. ‡ Berger, Ibid. p. 314.
§ Haller, Elem. Phys. ii. 36. || Haller, Ibid.
¶ Reports, ii. 428. ** Berger, *ubi autem*, p. 313. †† Ibid. p. 317.
‡‡ Mem. de la Societé de Phys. et de'Hist. Nat. de Geneve, vi. 310.
§§ Desprets, Ann. de Chim. et de Phys. xxvi. 338.
|||| Ibid.

Cabiais, 102°. Pulse, 140.
Guinea pig, 101°.4.
Adult guinea pig, 96°.368.*
Squirrel, 102°.
Rat, 102°.
Mouse, 99.
Marmot, when lively, 101°. When torpid, 67°, or even as low as 41°.5.

Pachydermata.
Elephant, 99°.5.
Sow, 104° to 107°.†
Boar, 104°.

Ruminantia.
Elk, 103°.
Chamois, 105°. In vagina, 104°.75.
Ox, 101° to 103.°
Calf 103° to 105°. In vagina, 101°.75, 104°.
Goat, 104°.
Sheep, 104° to 105°.‡ In vagina, 105°, 104°.33.
Lambs, 106°.
Cow with calf, in vagina, 102°.75.

Solipedes.
Horse, 100°.4 to 103°.§
Ass, 97° to 99°.5.

Cetacea.
Porpois, 100°.
Mean of cetacea, 101°.5.

Mean heat of Quadrupeds.

Monkeys,	99°.7
Carnivorous quadrupeds,	103°.264
Gnawers,	101°.939
Pachydermata,	105°.231
Ruminantia,	104°.029
Solipedes,	99°.644
Amphibia and cetacea,	101°.5

If we reckon the number of respirations in these animals 1, the beats of the pulse will be 3½, or there are 3½ beats of the pulse for every respiration.

Birds of Prey.
Mean heat, 104°.528.
Picæ, 106°.689.
Water fowl, 108°.361.
Herons and birds frequenting marshes, 107°.194.
Domestic fowls, 107°.24.
Passeres, 109°.71.

The following temperature of birds was determined by M. Despretz: ‖

Two adult ravens,	109°.238
Four young owls (flying well),	105°.638
An adult owl,	106°.646
An adult falcon,	106°.646
Three pigeons,	109°.346
Three young sparrows,	102°.344
An old sparrow,	107°.
Ditto, older,	107°.528
An old yellow hammer,	109°.184
Two young crows,	106°.166

Frogs and Sea Tortoises.
They have a temperature of about 5° above that of the air in which they live. Sir A. Carlisle found a frog 8° higher than the air.¶

Reptiles.
Testudo midas, 84° to 85°.
——— geometrica, 62°.5.
Testudo lateria, 54° to 65°.
Rana ventricosa, 77°.
Frogs, 3°.7 above the air.
Toad, 44°, the air being 36°.
Crocodile, 60°. Air, 37°.$\frac{1}{18}$.
Lacerta agilis, 71°. Air, 63°.5.
Green lizzard, 68°. Air, 68°.5.
Proteus anguinus, same as that of the air.

* Despretz, Ann. de Chim. et de Phys. xxvi. 338.
† Carlisle, Phil. Trans. 1805, p. 22. ‡ Ibid § Ibid.
‖ Ann. de Chim. et de Phys. xxvi. 338
¶ Phil. Trans. 1805, p. 22.

Serpents.

Viper, 68°. Air, 58°. John Hunter.

Green serpent, 88°. Air, 81°.5.

Fish.

About 0°.85 above that of the water in which they live.

Two carps,	53·042*
Two tenches,	52·772†
Water in which these fish lived,	51·494‡

Insects.

Caterpillars have a higher temperature than the same insects in the state of butterfly or chrysalis.§

Bee-hive, 88°. John Hunter.

Snails (Helix pomatia), 57°.66. Air, 55°.4.

Oyster, 82° on the sea-shore Ceylon.

Leech, same as that of the medium.

Within these few years very delicate experiments have been made by Becquerel, Breschet, &c. upon the temperature of different internal parts of the body by means of thermo-electricity. Two wires of different metals are soldered together and connected with a magneto-electric multiplier. The extremities of these wires are plunged into the part of the body whose temperature is wanted, the deviation of the needle marked, and water heated till it produce the same deviation. It is obvious that the internal part of the body experimented upon has in this case the same temperature as that of the water. The following tables exhibit the result of a set of experiments made by MM. Becquerel and Breschet upon three individuals distinguished by the letters A, B, and C. A and B were 20 years of age each, while C was 25.||

First series of experiments. Temperature of air 53°.

Biceps of the arm of A,	97°.75
Adjacent cellular tissue,	94 ·46
Mouth,	98 ·24
Biceps of the arm of B,	98 ·29
Adjacent cellular tissue,	95 ·81
Mouth,	98 ·06
Biceps of C,	98 ·186
Cellular tissue,	95 ·63
Mouth,	98 ·60

Black dog.	
Flexor muscle of thigh,	101°.12
Cellular tissue of neck,	98 ·60
Abdomen,	101 ·30
Thorax,	101 ·12
Another dog.	
Muscle of thigh,	100°.40
Thorax,	98 ·60
Abdomen,	100 ·58

Second series of experiments. Temperature of air 53°.

Biceps muscle of B,	89°.294
Cellular tissue,	96 044
Calf of leg,	98 ·42
Mouth,	98 ·60
Biceps of C,	98 ·42
Cellular tissue,	95°.954
Black dog.	
Muscle of thigh,	101°·48

Third series of experiments.

Mouth of B,	98°.33
Mouth of A,	98 ·51
Mouth of B,	98 ·60
Biceps of B,	98 ·78
Cellular tissue,	95°.864
Carp (*Ciprinus carpio*),	56 .30
Water,	55 .40

* Despretz, Ann. de Chim. et de Phys. xxvi. 338. † Ibid. ‡ Ibid. § Ibid. || Becquerel, Traité de l'Electricité, iv. p. 17.

Fourth series of experiments.

Poodle dog.			
Muscle of thigh,	100°.85	Thorax,	101°.93
		Brain,	101°.93

Becquerel found that when the muscles were made to contract, their temperature was increased about 0°.9. If while the wire is in the biceps muscle of the arm, the individual experimented on saws a piece of wood for about five minutes with that arm, the temperature increases about 1°.8. Agitation, motion, and in general every thing which occasions an afflux of blood has a tendency to raise the temperature of a muscle. When an artery going to a muscle is compressed so as to diminish the flow of blood to it, the temperature of the muscle sinks.

12. Ever since the publication of Mayow's tracts, or at least ever since the speculations of Dr Black on heat, became known to chemists, it has been the general opinion of physiologists that animal heat is generated by respiration. And in the year 1777, the theory of Dr Black, respecting latent and specific heat, was applied to the explanation of respiration by Dr Adair Crawford. The experiments on the specific heat of the gases, upon which Dr Crawford's Theory of Animal Heat is founded, were repeated by him again in London, with greater care and with a better apparatus, and the errors into which he had fallen, (which, however, did not affect his theory,) were corrected in the second edition of his work, published in 1788.

Dr Crawford's theory of animal heat was generally adopted by physiologists till the publication in 1812 of Sir Benjamin Brodie's very curious and important experiments on the influence of the brain in the production of animal heat.* These experiments show that the action of the brain or the nervous energy has considerable influence on the production of animal heat. He considered it as proved, that the volume of air was not altered by respiration, and that no other change took place in it except the substitution of carbonic acid gas for an equal volume of oxygen gas which had disappeared. His experiments were made upon rabbits.

(1.) A rabbit whose volume was 50 cubic inches in thirty minutes converted 25·3 cubic inches of oxygen gas into carbonic acid.

(2.) A rabbit of the volume 48 cubic inches in thirty minutes converted 28·22 cubic inches of oxygen into carbonic acid.

* Phil. Trans. 1812, p. 378.

(3.) A rabbit of the volume 48 cubic inches, in thirty minutes converted 28·22 cubic inches of oxygen into carbonic acid.

The mean of these three experiments gives the consumption of oxygen gas by the respiration of a rabbit, to amount to 27·25 cubic inches, or at the rate of 54½ cubic inches in the hour. Now, it has been stated above that the mean quantity of carbonic acid gas formed by the respiration of a man in an hour is 373·24 cubic inches, which is almost seven times greater than the quantity formed by the respiration of the rabbit. The average specific gravity of ten men tried by Mr Robertson was 0·89, and the average weight of each 145·9 lbs. or 4545 cubic inches,* or more than ninety-two times the bulk. Thus, it appears, (supposing Brodie's experiments to approach accuracy,) that the quantity of carbonic acid formed by the respiration of the rabbit is more than ten times as great (making allowance for the difference of bulk) as in man.

(1.) Mr Brodie having procured two rabbits of the same size and colour, divided the spinal marrow in the upper part of the neck of one of them. An opening was made in the trachea by means of which artificial breathing was kept up for half an hour. The heat of the rectum at the commencement of the experiment was 97°, at its termination 90°. The carbonic acid gas formed was 20·24 cubic inches, or about one-fourth less than in the living rabbit. The second rabbit killed at the same time, and in the same way, was placed in the same circumstances with the first, but without artificial respiration. At the end of the half hour, the thermometer in its rectum stood at 91°.

(2.) Two rabbits were killed by inoculation with woorara poison. In the first the lungs were inflated by artificial inspiration for half an hour. The thermometer in the rectum sunk from 98° to 91°. The carbonic acid formed was 25·55 cubic inches, or only one-sixteenth less than the normal quantity. The second rabbit was placed in exactly the same circumstances, but without artificial respiration. In half an hour, the thermometer in the rectum sunk to 92°.

(3.) Two rabbits were killed by woorara. In one the respiration was kept up artificially for thirty-five minutes. The thermometer in the rectum sunk from 97° to 90°. The carbonic acid formed was 31·75 cubic inches, which is at the rate of

* Phil. Trans. 1757, p. 30.

27·22 cubic inches in half an hour, or almost exactly the normal quantity. The second rabbit was placed in exactly the same circumstances, but without artificial respiration. The thermometer in the rectum sunk in thirty-five minutes to 90°5.

(4.) The experiment was repeated on another rabbit killed by the essential oil of bitter almonds. In half an hour, the thermometer in the rectum sunk to 90°. The carbonic acid evolved during the artificial respiration was 28·275 cubic inches, or somewhat more than the normal quantity.

If the accuracy of these experiments may be depended on, it seems to follow from them, that the chemical changes going on in the lungs are not the source of the heat of the animal. But it must not be concealed that they were repeated and varied by M. Legallois, who obtained different results. He found, in most cases, that when artificial respiration is kept up in a dead animal, the animal heat continues higher than when the lungs are not inflated. The result of his experiments was, that in general the heat of animals is directly proportional to the quantity of oxygen which they consume in a given time.*

The experiments of Legallois agree well with those of Despretz,† which are the most elaborate hitherto made upon respiration, and of which I shall now proceed to give an account.

13. According to Dr Black, part of the latent heat of the air inspired becomes sensible; and of course the temperature of the lungs, and the blood that passes through them, must be raised; and the blood thus heated, communicates its heat to the whole body. This opinion was ingenious, but it was liable to an unanswerable objection: for if it were true, the temperature of the body ought to be greatest in the lungs, and to diminish gradually as the distance from the lungs increases, which is not true. The theory, in consequence, was abandoned even by Dr Black himself, at least he made no attempt to support it.

Dr Crawford, who considered all the changes operated by respiration as taking place in the lungs, accounted for the origin of the animal heat almost precisely in the same way with Dr Black. According to him, the oxygen gas of the air combines in the lungs with the carbon emitted by the blood. During this combination, the oxygen gives out a great quantity of caloric, with

* Ann de Chim et de Phys. xxvi. 342.

† Ibid xxvi. 337.

which it had been combined; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the new-formed water in the state of vapour, and to raise considerably the temperature of the air inspired. According to this philosopher, then, the whole of the caloric which supports the temperature of the body is evolved in the lungs. His theory accordingly was liable to the same objection with Dr Black's; but Dr Crawford obviated it in the following manner: He found that the specific caloric of arterial blood was 1·0300, while that of venous blood was only 0·8928. Hence, he concluded, that the instant venous blood is changed into arterial blood, its specific caloric increases; consequently it requires an additional quantity of caloric to keep its temperature as high as it had been while venous blood. This addition is so great, that the whole new caloric evolved is employed: therefore, the temperature of the lungs must necessarily remain the same as that of the rest of the body. During the circulation, arterial blood is gradually converted into venous; consequently, its specific caloric diminishes, and it must give out heat. This is the reason that the temperature of the extreme parts of the body does not diminish.

Lavoisier, who was the first person that ascertained the composition of carbonic acid gas, considered the phenomena of respiration as analogous to combustion. Now, when oxygen combines rapidly with carbon or hydrogen, combustion takes place and heat is evolved. The evolution of heat in the lungs by the combination of the carbon of the blood with the oxygen of the atmosphere is analogous to combustion.

(1.) It follows, from the experiments of M. Despretz, that during the combustion of an avoirdupois pound of carbon, the quantity of heat evolved is sufficient to melt 104·2 lbs. of ice. Now, if the latent heat of water be 140°, 104·2 lbs. of ice will require to melt 14,588 degrees of heat, or, in other words, the heat evolved during the combustion of a pound of carbon would heat a pound of water 14,588°.

(2.) The oxygen gas requisite to consume a pound of carbon amounts to 2¾ lbs., which is equivalent to 55,082 cubic inches at the temperature of 60°. This oxygen gas combines with carbon, and is converted into its own volume of carbonic acid gas.

(3.) 55,082 cubic inches of oxygen gas when converted into carbonic acid gas give out 14,588° of heat; consequently, every

$3\frac{3}{4}$ cubic inches of oxygen gas, when converted into carbonic acid gas, give out 1° of heat.

(4.) From the experiments of Despretz, it farther appears, that when a pound of hydrogen is burnt, a quantity of heat is evolved, capable of melting 315·2 lbs. of ice, or the heat evolved would heat one pound of water 44,128 degrees. But for this combustion eight pounds of oxygen gas are required. Now eight pounds of oxygen gas are equivalent to 165,246 cubic inches. Hence every $3\frac{3}{4}$ cubic inches of oxygen gas, when they combine with hydrogen, evolve 1° of heat. It would appear from this that the heat evolved during the combustion of carbon and hydrogen, is proportional to the quantity of oxygen gas consumed.

These preliminary observations were necessary to enable us to understand the experiments of Despretz.

(1.) A rabbit was made to breathe during an hour and thirty-six minutes inclosed in a copper vessel, air-tight, but connected with two air-holders, by means of which a regular current of air was made to pass through the vessel. This air, after respiration, passed through a serpentine worm twelve feet long and surrounded with water, which cooled it to the same degree as when admitted to the vessel containing the animal. The volume of air respired was 2929 cubic inches. It was reduced by the breathing to 2919·5 cubic inches. The loss of volume was 9·5 cubic inches, or about $\frac{1}{308}$th of the original volume. The proportion of azotic gas was increased by 51·2 cubic inches. The elevation of temperature of the water gave the quantity of heat withdrawn from the animal by respiration, &c. 66 lbs. avoirdupois of water were heated 1°.26, or the quantity of heat given out by the animal in one hour and thirty-five minutes would have elevated the temperature of one pound of water 70.°84. The quantity of oxygen gas consumed was 247·5 cubic inches. Of these 187·7 cubic inches were converted into carbonic acid,* and Despretz supposes that the other 59·8 cubic inches combined with hydrogen, and were converted into water.

Now we have stated above that $3\frac{3}{4}$ cubic inches of oxygen when combined by combustion with carbon or hydrogen would evolve 1° of heat. Hence 247·5 cubic inches would evolve 66°. The heat actually given out by the animal was 70°·84, or 4°.8

* This is more than double the quantity of carbonic acid obtained by Sir B. Brodie in his experiments.

more than would have been produced by the quantity of oxygen gas actually consumed.

(2.) The experiment was repeated with the same rabbit. The heat given out by the animal during the experiment, being 100°, that furnished by the oxygen gas converted into carbonic acid

was, ...	64°.9
By the oxygen which formed water, .	20 ·9
Total, .	85 ·8

So that 14°.2 of the heat was due to other processes.

(3.) Six small rabbits fourteen days old were inclosed in the vessel for two hours and five minutes. The air passed through the vessel was 3019 cubic inches. It was reduced after the process to 2971 cubic inches. So that 48 cubic inches had disappeared. The oxygen gas consumed was 254·6 cubic inches, and the carbonic acid formed amounted to 180·3 cubic inches, so that 74·3 cubic inches of oxygen must have gone to the formation of water.

45·9 lbs, avoirdupois of water were heated 1°.796, or 1 lb. of water would have been heated 82°·43.

But the oxygen consumed would have evolved 67°.9, of which 48° is due to the formation of carbonic acid, and 19°.9 to the formation of water. The heated evolved exceeds by 14°.5, what could have been produced by the formation of carbonic acid and water.

(4.) A male rabbit evolved 100° heat, of which 68°.3 were due to the formation of carbonic acid, and 18°.4 to that of water. The 13°.3 were in excess.

(5.) Three male guinea pigs were enclosed in the apparatus for one hour and fifty-four minutes. The air which passed through the vessel was 2932 cubic inches, the oxygen gas consumed was 201·32 cubic inches, and the carbonic acid gas formed was 157·93 cubic inches, so that 43·39 cubic inches of oxygen went to the formation of water.

The air by the process became 2951·8 cubic inches, or the bulk increased by 19·8 cubic inches.

By the animal heat evolved during the experiment 51·38 lbs. avoirdupois of water were heated 1°.15. So that one pound would have been heated 59°.19.

The heat formed during the formation of the carbonic acid

was 42°.1, and during the formation of the water 11°.6, making together 53°.7; so that the heat evolved exceeded the heat generated by respiration by 5°.4.

(6.) Three female guinea pigs were confined in the apparatus. Heat evolved 100°, heat due to the formation of carbonic acid 69°.6, to that of water 19°.3. Both 88·9, or 11°.1 less than the heat evolved by the animal.

(7.) A dog aged five years was put into the apparatus. The experiment lasted one hour and thirty-one minutes. The air which passed through the vessel containing the dog was 2908·3 cubic inches; the volume of this air by the breathing of the dog was reduced to 2881·2 cubic inches, so that the diminution of volume was 27·1 cubic inches, or rather less than 1 per cent.

The oxygen gas consumed was 340·76 cubic inches; the carbonic acid formed was 229·94 cubic inches. Hence 110·82 cubic inches of the oxygen must have gone to the formation of water.

The heat evolved raised the temperature of 55·97 lbs. avoirdupois of water 1°.98. Or it would have raised the temperature of 1 lb. of water 110°.8.

The heat evolved by the formation of the carbonic acid is 61°.3, and that by formation of water 29°.56, making together 90°.8, or 20° less than the actual heat evolved.

(8.) A dog of eight months was enclosed in the apparatus for one hour, forty-two minutes. The volume of air used was 2922·6 cubic inches, reduced by the breathing of the dog to 2885·4 cubic inches. The loss was 37·2 cubic inches, or about $\frac{1}{78}$th part.

The oxygen consumed was 254·35 cubic inches; the carbonic acid formed was 169·47 cubic inches, so that 84·88 cubic inches of the oxygen must have been consumed in forming water.

The heat evolved heated 46 lbs. avoirdupois of water 1·98, or it would have raised the temperature of 1 lb. of water 88°.76.

The heat evolved by the formation of the carbonic acid gas was 45°.19; and that by the formation of water 22°.63; making together 67°.82, or 20°.94 less than the actual heat evolved.

During this experiment there were 46·44 cubic inches of azotic gas evolved.

(9.) Two dogs six weeks old were enclosed in the apparatus. The experiment lasted one hour and forty-two minutes. The volume of air used was 2871·6 cubic inches. It was reduced by

breathing to 2803·5 cubic inches; so that 68·1 cubic inches, or about $\frac{1}{42}$d of the whole disappeared during the breathing. The azotic gas of the air breathed was increased by 66·94 cubic inches.

The oxygen consumed was 380·37 cubic inches; the carbonic acid formed was 245·2 cubic inches. Hence 135·17 cubic inches of the oxygen must have been consumed in the formation of water.

The heat evolved by the dogs raised the temperature of 56 lbs. avoirdupois of water 2°.43, or would have raised the heat of 1 lb. of water 136°.

The heat evolved by the formation of the carbonic acid was 65°.39, and that by the formation of water 36°.04, making together 101°.43. This is 34°.57 less than the heat actually evolved.

(10.) A male cat, more than two years of age, was enclosed in the apparatus. The experiment lasted one hour and thirty-five minutes. The quantity of air used was 2922·2 cubic inches. It was reduced by the breathing of the cat to 2901 cubic inches, so that the loss of volume was 21·2 cubic inches, or about $\frac{1}{138}$th of the original volume. The proportion of azote in the air respired was increased by 31·97 cubic inches.

The oxygen consumed was 178·8 cubic inches; the carbonic acid formed was 125·7 cubic inches; so that 53·1 cubic inches of the oxygen must have been consumed in the formation of water.

The heat evolved heated 56 lbs. avoirdupois of water, 1°.044; or it would have raised the temperature of 1 lb. of water, 58°.46.

The heat evolved by the formation of the carbonic acid was 33°.52, and that by the formation of water was 14°.16; making together 47°.68, or 10°.78 less than the heat actually evolved.

(11.) Three adult male pigeons were put into the apparatus. The experiment lasted one hour and thirty-two minutes. The volume of air used was 2909·3 cubic inches. It was reduced by the breathing of the animal to 2907·9 cubic inches. So that the loss of volume was 1·4 cubic inches, or about $\frac{1}{2067}$th of the original quantity. The proportion of azotic gas in the air respired was increased by 43·33 cubic inches.

The oxygen gas consumed was 194·4 cubic inches; the carbonic acid formed was 149°.5: so that 44·9 cubic inches of the oxygen gas must have been consumed in the formation of water.

The heat evolved heated 56 lbs. avoirdupois of water 1°.159, or it would have raised the temperature of 1 lb. of water 64°.9.

The heat evolved by the formation of carbonic acid gas was 3°.87, and that by the formation of water was 11°.97; making together 51°.84, or 13°.1 less than the heat actually evolved.

(12.) An adult duck was experimented on in the same way. If we suppose the heat evolved to have been 100°; that resulting from the formation of carbonic acid will be 60°.5, and that from the formation of water 19°.2; making together 79·7, or 20°.3 less than the heat actually evolved.

(13.) An adult cock was experimented on in the same way. If we suppose the heat evolved to have been 100°; that evolved by the formation of carbonic acid will be 60°.5, and that from the formation of water 19°.2; making together 79°, or 20°.3 less than the heat actually evolved.

(14.) An adult Virginian duck was enclosed in the apparatus. The experiment lasted one hour and twenty-five minutes. The volume of air employed was 2937·5 cubic inches, reduced by the breathing of the animal to 2919·3 cubic inches. The loss of volume was 18·2 cubic inches, or about $\frac{1}{161}$ of the original volume. The proportion of azotic gas in the air respired was increased by 44·36 cubic inches.

The oxygen gas consumed was 160·35 cubic inches. The carbonic acid formed was 97·71 cubic inches; so that 62·54 cubic inches of the oxygen must have been consumed in forming water.

The heat given out heated 56 lbs. of water 0°.99; or it would have raised the temperature of 1 lb. of water 55°.44.

The heat evolved by the formation of the carbonic acid was 26°.06; and that by the formation of water 16°.70; making together 42°.75; or 12°.69 less than the heat actually evolved.

(15.) Four owls experimented upon. If the heat given out was 100°, that evolved by the formation of the carbonic acid was 56°.3, and that by the formation of water 18°.3, making together 74°.6; or 25°.4 less than the heat actually evolved.

(16.) Four magpies fed on animal food were experimented on. If the animal heat given out was 100°, that given out by the formation of carbonic acid was 57°.6, and that by the formation of water 17°.8; making together 75°.4, or 24°.6 less than the heat actually evolved.

If these experiments of Despretz have been accurately performed,

it follows from them that there is nothing fixed or certain either in the ratio between the oxygen consumed and the carbonic acid formed, or in the diminution of volume of the air by breathing; or of the heat evolved. In general the more oxygen gas consumed the greater is the quantity of heat evolved; though this does not hold rigidly in every experiment.

That the reader may see at a glance the variations in these experiments, the following table has been calculated, showing the volume of oxygen consumed, and of carbonic acid formed, the diminution of the volume of air breathed, and the heat evolved, supposing each animal to have breathed ten minutes:

	Oxygen consumed in cubic inches.	Carbonic acid formed in cubic inches.	Diminutions of bulk of air.	Heat evolved.*
Man,	119·	119·	uncertain.	uncertain.
Rabbit,	25·7	19·5	$\frac{1}{305}$	7°.36
Six small rabbits,	20·4	14·4	$\frac{1}{70}$	6 .44
Three male guinea pigs,	17·6	13·8	$\frac{1}{148}$†	5 .18
A dog, five years old,	37·4	25·2	$\frac{1}{107}$	12 .17
A dog, eight months old,	24·9	16·6	$\frac{1}{78}$	8 .70
Two dogs, six weeks old,	37·3	24·0	$\frac{1}{42}$	13 .33
A male cat,	18·9	13·2	$\frac{1}{138}$	6 .15
Three adult male pigeons,	21·1	16·2	$\frac{1}{207}$	7 .05
An adult Virginian duck,	18·8	11·5	$\frac{1}{161}$	6 .52

It follows from these experiments, that the whole animal heat developed in the living animal is not the consequence of the combination of the oxygen of the atmosphere with carbon and hydrogen. If we reckon the animal heat evolved in these experiments 100°, then the portion of it due to the combination of the oxygen of the atmosphere with carbon and hydrogen during the circulation of the blood through the body will be 82°.‡ Consequently, 18°, or almost one-fifth of the whole, must be owing to other processes not yet sufficiently appreciated. What renders these conclusions somewhat uncertain, is the great diversity in the ratios of the heat evolved, and the oxygen consumed in the different ex-

* This column indicates the number of degrees that the temperature of one pound of water would be heated by the heat given out during ten minutes breathing.

† In this case the bulk of the air was increased by breathing instead of being diminished.

‡ Dr Winn has ascertained that when the elastic coat of an artery is stretched, heat is evolved (Phil. Mag. (3d series) xiv. 174), and he conceives that this evolution will supply the surplus heat of the animal above that furnished by respiration. Not considering that when the coat contracts it must again absorb all the heat evolved by the stretching, as was long ago proved to be the case with caoutchouc by Mr Gough.

periments. If we reckon the animal heat evolved to be 100°, the quantity of it due to the consumption of oxygen varies in the different experiments from 93°.1 to 74°.5. This variation will be best understood if we arrange the experiments in the form of a table:

	Heat evolved.	Heat from consump. of oxygen.
Rabbit, ...	100°	93°.1
Six small rabbits, . .	100	83 ·58
Three male guinea pigs, .	100	90 ·72
A dog, five years old, .	100	81 ·94
A dog, eight months old, .	100	76 ·40
Two dogs, six weeks old, .	100	74 ·57
A male cat, .	100	81 ·56
Three adult male pigeons, .	100	79 ·87
An adult Virginian duck, .	100	77 ·11
Mean, . . .	100	82

To be able to compare the breathing of different animals together, as far as the consumption of oxygen is concerned, it would be necessary to know the weight of the different animals subjected to experiment. This, unfortunately, Despretz has neglected to determine.

Nearly about the time (1823) that Despretz was occupied with the experiments just detailed, a similar set of experiments was made by M. Dulong. His method of proceeding was nearly similar to that of Despretz. It will, therefore, be sufficient to state here the results which he obtained.

His experiments were made upon six kinds of animals, namely, the dog, the cat, the hawk, the cabiai, the rabbit, and the pigeon; and each was several times repeated.

The volume of oxygen consumed by the respiration of the dog, the cat, and the hawk was a third more than that of the carbonic acid gas formed; and only one-tenth more in the rabbit, the cabiai, and the pigeon. Dulong conceives that this difference is connected with the different kind of food on which these animals live.

More azote is given out during the respiration of herbivorous animals than of carnivorous. In the former the bulk of the air expired generally exceeds that of the air inspired.

In carnivorous animals the heat due to the formation of carbonic acid gas amounts to 0·49 to 0·55 of the whole heat evolved; in frugivorous animals to from 0·65 to 0·75.

If we suppose with Lavoisier and Despretz that the portion of

oxygen which disappears above what can be accounted for by the formation of carbonic acid gas to the formation of water. Then from 0·69 to 0·80 of the whole heat evolved is produced by respiration, and from 0·31 to 0·20 by other and unknown agencies.

I have myself little or no doubt that the whole animal heat evolved is owing to the conversion of the oxygen gas absorbed into carbonic acid and water during the circulation. In Déspretz's experiments the animals were exposed to a greater cooling agency, from being surrounded by cold water, than in ordinary respiration. If we admit that the great object of respiration is the generation of heat, and adopt the statement made in this chapter as accurate, there will be no difficulty in calculating the average quantity of heat produced in man during twenty-four hours. The blood in an adult is about 26 lbs. avoirdupois, and it completes its circulation through the body in about 3·06 minutes. Hence, 8½ lbs. of blood pass through the lungs in a minute.

During each inspiration, 16 cubic inches of air enter the lungs, and 0·425 lb. of blood is exposed to its action. During every inspiration 0·6432 cubic inch of oxygen gas is absorbed by the blood; and as every 4·75 cubic inches of oxygen gas, combining with carbon or hydrogen, evolved 1° of heat, it follows that the oxygen absorbed during each inspiration evolves (during its circulation in the blood-vessel) 0·17°, or nearly one-sixth of a degree of heat. The oxygen absorbed during 6 inspirations produces 1° of heat. Hence, the heat evolved by respiration in twenty-four hours would heat 1 lb. of water, 4800°, or, supposing none of it dissipated, it would heat a middle-sized man 33° in twenty-four hours.

Those who inhabit cold climates require more heat than those who live in hot climates. Hence, doubtless, the reason of the great appetites, and the vast quantity of whale oil swallowed by the Esquimaux, and the small appetite and vegetable diet of the inhabitants of the torrid zone.

This subject has been placed in a very clear light by Liebig in his late work on *Animal Chemistry*. Respiration, he conceives, is intended to generate heat, without which no animal could live. This is effected by the combination of the oxygen of the atmosphere with the carbon and hydrogen of the food. He considers the unoxygenized portion of food (starch, gum, and sugar) to be intended for the production of animal heat. But it is difficult

to see how these substances get into the circulation, as no trace of them can be found in the blood. The heat generated is proportional to the food digested. In hot climates, the waste of heat being small, but little food is required, whereas in cold climates the waste of heat is great, and hence the appetite is greatly increased. Liebig conceives that, in consequence of the coldness of the atmosphere in frigid climates, a greater proportion of oxygen is inhaled than in hot climates; but as the air inhaled is heated in the lungs to 98°, and as the azotic gas constitutes four-fifths of this air, one would expect that the heat necessary to heat this azotic gas from a very low temperature to 98°, would fully compensate for any increase in the density of the oxygen gas. The number of respirations per minute ought to increase in cold climates, or, what is more probable, the per centage of carbonic acid evolved, and of oxygen absorbed during each respiration ought to increase.

We want additional experiments. The statement given in this chapter applies only to the summer. I am not aware of any attempt to determine the carbonic acid formed by respiration during winter. It would be interesting to know the per centage of carbonic acid given out by breathing in India and in St Petersburg or Stockholm. The subject is well worth the attention of men of science in India.

CHAPTER III.

OF THE ACTION OF THE KIDNEYS.

A VERY great proportion of blood passes through the kidneys; indeed, we have every reason to conclude that the whole of the blood passes through them very frequently. These organs separate the urine from the blood, to be afterwards evacuated without being applied to any purpose useful to the animal.

The kidneys are absolutely necessary for the continuance of the life of the animal; for it dies speedily when they become by disease unfit to perform their functions: therefore the change which they produce in the blood is a change necessary for qualifying it to answer the purposes for which it is intended.

In a preceding chapter of this work, a very minute account

has been given of urine, and of the constituents which it contains, and the proportion of each voided from an adult in good health during the course of twenty-four hours. The following abstract may be considered as exhibiting an approximation to a mean:

1. The urea varies from	185·3 grains	to	509·3
2. The uric acid, ...	1·373	...	14·307
3. Fixed salts, ...	378·	...	748.
4. Earthy phosphates,	0·447	...	30·25
5. Common salt, ...	0·247	...	116·5
6. Sulphuric acid, ...	15·25	...	57·5
7. Phosphoric acid,	0·17	...	25·37

It was long believed by physiologists that urea, uric acid, phosphoric and sulphuric acid were generated in the kidneys by the peculiar action of these organs. This supposition was founded on the unsuccessful attempts of chemists to detect these substances in the blood. But MM. Prevost and Dumas showed in 1823, that this opinion was ill founded.* They cut out the kidneys of dogs, cats, and rabbits. The animals usually died in about five days after the operation, except the rabbits which did not live so long. On examining the blood of these animals drawn a little before death, they succeeded in finding a considerable quantity of urea in it. They were not successful in finding phosphoric and sulphuric acid in that blood, but their attempts were made only in a cursory manner. It is evident from these experiments that the urea in urine is not secreted in the kidneys but only eliminated. Doubtless this is the case with all the other peculiar substances found in the urine. The reason why they cannot be detected in the blood must be, that they are eliminated by the kidneys as fast as formed; so that they never accumulate in the blood in any sensible quantity. Unless when, by the removal of the kidneys, this removal is prevented.

The kidneys, then, are not organs of secretion but of elimination. In what organ the urea, uric acid, and other peculiar substances of the urine are formed, is not yet known. It is probable that the albumen, fibrin, or hematosin of the blood, undergoes decomposition in some organ for the formation of some substance useful in the animal economy, and that the urea and uric acid are substances formed at the same time, which not being use-

* Ann. de Chim. et de Phys. xxiii. 90.

ful to the animal economy, are immediately eliminated by the kidneys.

Professor Liebig, in his late work on Animal Chemistry, p. 136, has made a remarkable observation. Protein + 3 atoms water may be resolved into choleic acid and urate of ammonia.

Protein is,	.	$C^{48}\ H^{36}\ Az^{6}\ O^{14}$
3 atoms water,	.	$H^{3}\ \ O^{3}$
Total,	.	$C^{48}\ H^{39}\ Az^{6}\ O^{17}$
Choleic acid is,		$C^{38}\ H^{33}\ Az\ O^{11}$
Uric acid,	.	$C^{10}\ H^{4}\ Az^{4}\ O^{6}$
Ammonia,	.	$H^{3}\ Az$
Total,	.	$C^{48}\ H^{40}\ Az^{6}\ O^{17}$

Differing only by an atom of hydrogen. It would not be surprising, then, if the uric acid and urea as well as the choleic acid were formed in the liver.

It has been long known that in diseases of the liver the quantity of urea in the urine is diminished. Is it not possible that the albumen of blood is decomposed into bile and urea? The urea and uric acid are rich in azote, while the bile contains but little. Whether this conjecture be well or ill founded, there can be little doubt that the formation of these two substances must be the result of the decomposition of the constituents of blood, to form some secretion of importance to the animal economy. The importance of the liver as a secreting organ is obvious from the great derangement of the system which takes place when it is diseased.

Liebig conceives that the matter of bile is absorbed by the lacteals, and employed in the production of heat by its union with oxygen during the function of respiration. But certainly this cannot be the case unless the bile undergoes decomposition. For in the disease called jaundice, when the bile is absorbed into the system, the skin and eyes are tinged yellow. The methods of determining the quantity of bile secreted are so vague that no reliance can be placed on them.

Chossat has shown that the quantity of solid matter in the urine increases with the food, and is proportional to it, supposing the whole food to be digested.

When a person is fed on bread the quantity of solid urine voided is less than when he is fed on eggs, and when he is fed on eggs less than when fed on meal. The ratios are nearly 5 : 7 : 9.*

The quantity of solid matter in the urine is proportional to that of azote in the food.†

	Ounces.	Grains.
Food,	82	77
Urine,	56	64
Difference,	26	13

When the food is egg $\frac{10}{11}$ths of the azote of the food found in the urine; but $\frac{14}{15}$ths of the carbon is wanting, because it is given off by the lungs.

The person fed on one meal a day, generous and copious. First experiment lasted 32 days; second, 35 days.

Mean urine rendered daily in 24 hours, dividing the day into 6 periods of 4 hours each:

	1st Series. Mean urine. Solid.	2d Series. Mean urine. Solid.	3d Series.	4th Series.
1st period, from 2 to 6 P. M.,	55·3 gr.	61·4 gr.	197·1	33·8
2d do. from 6 to 10 P. M.,	88·7	102·8		
3d do. from 10 P. M. to 2 A. M.,	107·9	218·9	208·7	35·9
4th do. from 2 to 6 A. M.,	85·6	106·3		
5th do. from 6 to 10 A. M.,	100·1	77·2	211·2	30·3
6th do. from 10 A. M. to 2 P. M.,	70·4	77·2		
Total,	508·	643·8	617·0	100·0

The quantity of food in the second series was greater; the kind the same. It is presumed that the food was taken just before the beginning of the first period.

The greatest quantity is from 8 to 12 hours after food; the least just after taking food.

In the fourth series the food was much diminished and of inferior quality.

The secretion of solid urine is at a minimum the first two hours after taking food, increases much the next two hours, and maintains nearly the same rate during the next four hours.

When food was only taken once in 48 hours there was a feeling of cold the second day.

* Jour. de Phys. v. 84. † Ibid. p. 86.

Food only taken once in 48 hours. The food was vegeto-albuminous, drink tea. Quantity double of that taken once in 24 hours. Time of eating, the end of the first of the 6 periods of 8 hours each. Experiment lasted 16 days.

	Solid urine.
1st period 8 hours,	112·1
2d do. 8 to 16 hours,	141·6
3d do. 18 to 24 do.	90·8
4th do. 24 to 32 do.	111·9
5th do. 32 to 40 do.	84·5
6th do. 40 to 48 do.	54·7
	595·6

Two repasts a day, food vegeto-animal, the first at 9 A. M., the second the most abundant at 5 P. M. Periods of 6 hours each, commence with it.

	Solid urine.	Solid urine.
1st period,	100·5	151·1
2d do.	110·3	196·1
3d do.	107·1	165·9
	317·9	513·1

Three meals a day. Food the same. At 8 A. M., 1 P M., and 9 P. M.

	Solid urine.
1st period, 7 A. M. to 3 P. M.,	142·1 grains
2d do. 3 P. M. to 11 P. M.,	158·6
3d do. 11 P. M. to 7 A. M.,	94·2
	394·9

By a cold bath (82°.76), the aqueous portion of the urine is sextupled, by a warm bath (99°), not increased, pulse 132. In the cold bath the pulse became slower, sinking at last (in two hours) to 40 in a minute, from 60. The solid part of urine is also increased in the cold bath by the increase of the watery portion.

The quantity of solid urine diminishes in the evening when the nervous energy is diminished, and requires to be restored by sleep.

The secretion of solid urine is a little increased by sleep, about

$\frac{1}{29}$, when the strength is unimpaired, and also when enfeebled by scanty food.

CHAPTER IV.

OF PERSPIRATION.

It is well known that considerable quantities of matter in the state of vapour are constantly emitted from the skin. This vapour is called *perspirable matter or perspiration.* When, by the sudden application of cold, the exhalents by which this vapour is thrown out are shut, the system becomes deranged, and what we call in common language *a cold* is the consequence. All the facts respecting the quantity and nature of this perspired matter at present known have been stated under the title of perspiration and sweat in a preceding chapter of this work, to which the reader is referred. Nothing is known respecting the nature of the process. The exhalent vessels are situated in the skin, and, according to modern anatomists, are twisted in the form of a cork-screw. They are exceedingly small in diameter, and their open mouths terminate just under the epidermis. The process of perspiration is very similar to respiration. Whether the external air has any thing to do with it has not been ascertained; but it is probable that it has. Water, carbonic acid, lactic acid, and an oily matter having a peculiar smell, are thrown out from the blood-vessels of the skin, and doubtless in considerable quantity.

It has been supposed that the skin has the property of *absorbing moisture* from the air, but this opinion has not been confirmed by experiments, but rather the contrary.

The chief arguments in favour of absorption of the skin have been drawn from the quantity of moisture discharged by urine, being, in some cases, not only greater than the whole drink of the patient, but even than the whole of his drink and food. But it ought to be remembered that, in diabetes, the disease here alluded to, the weight of the body is continually diminishing, and therefore part of it must be constantly thrown off. Besides, it is scarcely possible in that disease to get an accurate account of the food swallowed by the patients; and in those cases where very

accurate accounts have been kept, and where deception was not so much practised, the urine was found not to exceed the quantity of drink.* In a case of diabetes, related with much accuracy by Dr Gerard, the patient was bathed regularly during the early part of the disease in warm water, and afterwards in cold water: he was weighed before and after bathing, and no sensible difference was ever found in his weight.† Consequently, in that case, the quantity absorbed, if any, must have been very small.

It is well known that thirst is much alleviated by cold bathing. By this plan Captain Bligh kept his men cool and in good health during their very extraordinary voyage across the South Sea. This has been considered as owing to the absorption of water by the skin. But Dr Currie had a patient who was wasting fast for want of nourishment, a tumour in the œsophagus preventing the possibility of taking food, and whose thirst was always alleviated by bathing; yet no sensible increase of weight, but rather the contrary, was perceived after bathing. It does not appear, then, that in either of these cases water was absorbed.

Farther, Seguin has shown that the skin does not absorb water during bathing, by a still more complete experiment: He dissolved some mercurial salt in water, and found that the mercury produced no effect upon a person that bathed in the water, provided no part of the cuticle was injured: but upon rubbing off a portion of the cuticle, the mercurial solution was absorbed, and the effects of the mercury became evident upon the body. Hence it follows irresistibly, that water, at least in the state of *water*, is not absorbed by the skin when the body is plunged into it, unless the cuticle be first removed.

This may perhaps be considered as a complete proof that no such thing as absorption is performed by the skin; and that therefore the appearance of carbonic acid gas, which takes place when air is confined around the skin, must be owing to the emission of carbon. But it ought to be considered, that, although the skin cannot absorb water, this is no proof that it cannot absorb other substances; particularly that it cannot absorb oxygen gas, which is very different from water. It is well known that water will not pass through bladders, at least for some time: yet Dr Priestley found that venous blood acquired the colour of arterial blood

* See Rollo on Diabetes. † Ibid. ii. 73.

from oxygen gas, as readily when these substances were separated by a bladder as when they were in actual contact. He found, too, that when gases were confined in bladders, they gradually lost their properties. It is clear from these facts, that oxygen gas can pervade bladders: and if it can pervade them, why may it not also pervade the cuticle? Nay, farther, we know from the experiments of Cruickshanks, that the vapour perspired passes through leather, even when prepared so as to keep out moisture, at least for a certain time. It is possible, then, that water, when in the state of vapour, or when dissolved in air, may be absorbed, although water, while in the state of water, may be incapable of pervading the cuticle. The experiments, therefore, which have hitherto been made upon the absorption of the skin are insufficient to prove that air and vapour cannot pervade the cuticle, provided there be any facts to render the contrary supposition probable.

Now, that there are such facts cannot be denied. I shall not indeed produce the experiment of Van Mons as a fact of that kind, because it is liable to objections, and at best is very indecisive. Having a patient under his care who, from a wound in the throat, was incapable for several days of taking any nourishment, he kept him alive during that time by applying to the skin, in different parts of the body, several times a day, a sponge dipped in wine or strong soup.* A fact mentioned by Dr Watson is much more important, and much more decisive. A lad at Newmarket, who had been almost starved in order to bring him down to such a weight as would qualify him for running a horse race, was weighed in the morning of the race day; he was weighed again an hour after, and was found to have gained 30 ounces of weight; yet in the interval he had only taken half a glass of wine. Here absorption must have taken place, either by the skin or lungs, or both. The difficulties in either case are the same; and whatever renders absorption by one probable, will equally strengthen the probability that absorption takes place by the other.†

* Phil. Mag. vi. 95.

† Watson's Chemical Essays, iii. 101. The Abbé Fontana also found that, after walking in moist air for an hour or two, he returned home some ounces heavier than when he went out, notwithstanding he had suffered considerable evacuation from a brisk purge purposely taken for the experiment. This increase, indeed, might be partly accounted for by the absorption of moisture by his clothes.

MM. Becquerel and Breschet have found that when a dog or rabbit is deprived of its hair, and the whole body covered with a varnish to prevent perspiration, the animal always died in a few hours, while the temperature of the surface rapidly sank. In a rabbit from 101° to 76° in an hour. In another the temperature of the muscles of the thigh in an hour and a-half was only 5½° above that of the atmosphere.*

CHAPTER V.

OF ASSIMILATION.

WE have now seen the progress of digestion, and the formation of blood, as far at least as we are acquainted with it. But to what purposes is this blood employed, which is formed with so much care, and for the formation of which so great an apparatus has been provided? It answers two purposes. The parts of which the body is composed, bones, muscles, ligaments, membranes, &c. are continually changing. In youth they are increasing in size and strength, and in mature age they are continually acting, and consequently continually liable to waste and decay. They are often exposed to accidents, which render them unfit for performing their various functions; and even when no such accident happens, it seems necessary for the health of the system that they should be now and then renewed. Materials, therefore, must be provided for repairing, increasing, or renewing all the various organs of the body; phosphate of lime and gelatin for the bones, fibrin for the muscles, albumen for the cartilages and membranes, &c. Accordingly, all these substances are laid up in the blood; and they are drawn from that fluid, as from a storehouse, whenever they are required. The process by which the different ingredients of the blood are made part of the various organs of the body is called ASSIMILATION.

Over the nature of assimilation the thickest darkness still hangs: there is no key to explain it, nothing to lead us to the knowledge of the instruments employed. Facts, however, have been accumulated in sufficient numbers to put the existence of the process beyond the reach of doubt. The healing, indeed, of

* Comptes Rendus, xiii. 791.

every fractured bone, and every wound of the body, is a proof of its existence, and an instance of its action.

Every organ employed in assimilation has a peculiar office; and it always performs this office whenever it has materials to act upon, even when the performance of it is contrary to the interest of the animal. Thus the stomach always converts food into chyme, even when the food is of such a nature that the process of digestion will be retarded rather than promoted by the change. If warm milk, for instance, or warm blood, be thrown into the stomach, they are always decomposed by that organ, and converted into chyme; yet these substances are much more nearly assimilated to the animal before the action of the stomach than after it. The same thing happens when we eat animal food.

On the other hand, a substance introduced into an organ employed in assimilation, if it has undergone precisely the change which that organ is fitted to produce, is not acted upon by that organ, but passed on unaltered to the next assimilating organ. Thus it is the office of the intestines to convert chyme into chyle. Accordingly, whenever chyme is introduced into the intestines, they perform their office, and produce the usual change; but if chyle itself be introduced into the intestines, it is absorbed by the lacteals without alteration. The experiment, indeed, has not been tried with true chyle, because it is scarcely possible to procure it in sufficient quantity; but when milk, which resembles chyle pretty accurately, is thrown into the jejunum, it is absorbed unchanged by the lacteals.*

Again, the office of the blood-vessels, as assimilating organs, is to convert chyle into blood. Chyle, accordingly, cannot be introduced into the arteries without undergoing that change; but *blood* may be introduced from another animal without any injury, and consequently without undergoing any change. This experiment was first made by Lower, and it has since been very often repeated.

Also, if a piece of fresh muscular flesh be applied to the muscle of an animal, they adhere and incorporate without any change, as has been sufficiently established by the experiments of Mr J. Hunter; and Buniva has ascertained, that fresh bone may, in the same manner, be engrafted on the bones of animals of the same or of different species.†

* Fordyce on Digestion, p. 189.

† Phil. Mag. vi. 308.

In short, it seems to hold, at least as far as experiments have hitherto been made, that foreign substances may be incorporated with those of the body, provided they be precisely of the same kind with those to which they are added, whether fluid or solid. Thus chyle may be mixed with chyle, blood with blood, muscle with muscle, and bone with bone. The experiment has not been extended to the other animal substances, the nerves, for instance; but it is extremely probable that it would hold with respect to them also.

On the other hand, when substances are introduced into any part of the body which are not the same with that part, nor the same with the substance upon which that part acts, provided they cannot be thrown out readily, they destroy the part, and perhaps even the animal. Thus foreign substances introduced into the blood very soon prove fatal; and introduced into wounds of the flesh or bones, they prevent these parts from healing.

Although the different assimilating organs have the power of changing certain substances into others, and of throwing out the useless ingredients, yet this power is not absolute, even when the substances on which they act are proper for undergoing the change which the organs produce. Thus the stomach converts food into chyme, the intestines chyme into chyle, and the substances which have not been converted into chyle are thrown out of the body. If there happen to be present in the stomach and intestines any substance which, though incapable of undergoing these changes, at least by the action of the stomach and intestines, yet has a strong affinity, either for the whole chyme and chyle, or for some particular part of it, and no affinity for the substances which are thrown out, that substance passes along with the chyle, and in many cases continues to remain chemically combined with the substance to which it is united in the stomach, even after that substance has been completely assimilated, and made a part of the body of the animal. Thus there is a strong affinity between the colouring matter of madder and phosphate of lime. Accordingly, when madder is taken into the stomach, it combines with the phosphate of lime of the food, passes with it through the lacteals and blood-vessels, and is deposited with it in the bones, as was proved by the experiments of Bechier* and

* Phil. Trans. 1736, p. 287.

Duhamel.* In the same manner, musk, indigo, &c. when taken into the stomach, make their way into many of the secretions.

These facts show us that assimilation is a chemical process from beginning to end; that all the changes are produced according to the laws of chemistry; and that we can even derange the regularity of the process by introducing substances whose mutual affinities are too strong for the organs to overcome.

It cannot be denied, then, that the assimilation of food consists merely in a certain number of chemical decompositions which that food undergoes, and the consequent formation of certain new compounds. But are the *agents* employed in assimilation merely chemical agents? We cannot produce any thing like these changes on the food out of the body, and therefore we must allow that they are the consequence of the action of the animal organs. But this action, it may be said, is merely the secretion of particular juices, which have the property of inducing the wished-for change upon the food; and this very change would be produced out of the body, provided we could procure these substances, and apply them in proper quantity to the food. If this supposition be true, the specific action of the vessels consists in the secretion of certain substances; consequently the cause of this secretion is the *real* agent in assimilation. Now, can the *cause* of this secretion be shown to be merely a chemical agent? Certainly not. For in the stomach, where only this secretion can be shown to exist, it is not always the same, but varies according to circumstances. Thus eagles at first cannot digest grain, but they may be brought to do it by persisting in making them use it as food. On the contrary, a lamb cannot at first digest animal food, but habit will also give it this power. In this case, it is evident that the gastric juice changes according to circumstances.

The presence of some agent, different from a mere chemical power, will be still more evident, if we consider the immunity of the stomach of the living animal during the process of digestion. The stomach of animals is as fit for food as any other substance. The gastric juice, therefore, must have the same power of acting on it, and of decomposing it, that it has of acting on other sub-

* Phil. Trans. 1740, p. 390. The fact was mentioned by Mizaldus in a book published in 1536, entitled, Memorabilium, utilium ac jucundorum Centuriæ novem.

stances; yet it is well known that the stomach is not affected by digestion while the animal retains life; though, as Mr Hunter ascertained, the very gastric juice which the living stomach secretes, often dissolves the stomach itself after death. * Now what is the power which prevents the gastric juice from acting on the stomach during life? Certainly neither a chemical nor mechanical agent, for these agents must still retain the same power after death. We must, then, of necessity conclude, that there exists in the animal an agent very different from chemical and mechanical powers, since it controls these powers according to its pleasure. These powers, therefore, in the living body, are merely the servants of this superior agent, which directs them so as to accomplish always one particular end. This agent seems to regulate the chemical powers, chiefly by bringing only certain substances together which are to be decomposed, and by keeping at a distance those substances which would interfere with, or diminish, or spoil the product, or injure the organ; and we see that this separation is always attended to even when the substances are apparently mixed together; for the very same products are not obtained, which would be obtained by mixing the same substances together out of the body, that are produced by mixing them in the body; consequently all the substances are not left at full liberty to obey the laws of their mutual affinities. The superior agent, however, is not able to exercise an unlimited authority over the chemical powers; sometimes they are too strong for it: some substances, accordingly, as madder, make their way into the system; while others, as arsenic, decompose and destroy the organs of the body themselves.

But it is not in digestion alone that this superior agent makes the most wonderful display of its power; it is in the last part of assimilation that our admiration is most powerfully excited. How comes it that the precise substances wanted are always carried to every organ of the body? How comes it that fibrin is always regularly deposited in the muscles, and phosphate of lime in the bones? And, what is still more unaccountable, how comes it that prodigious quantities of some one particular substance are formed and carried to a particular place, in order to supply new wants which did not before exist? A bone, for example, becomes diseased

* Phil. Trans. 1772, p. 447.

and unfit for the use of the animal; a new bone, therefore, is formed in its place, and the old one is carried off by the absorbents. In order to form this new bone, large quantities of phosphate of lime are deposited in a place where the same quantity was not before necessary. Now, who informs this agent that an unusual quantity of phosphate of lime is necessary, and that it must be carried to that particular place? Or, granting, as is most probable, that the phosphate of lime of the old bone is partly employed for this purpose, who taught this agent that the old bone must be carried off, new-modelled, and deposited and assimilated anew? The same wonders take place during the healing of every wound, and the renewing of every diseased part.

But neither in this case is the power of this agent over the chemical agents which are employed absolute. We may prevent a fractured bone from healing, by giving the patient large quantities of acids. And unless the materials for new-wanted substances be supplied by the food, they cannot in many cases be formed at all. Thus the canary bird cannot complete her eggs unless she be furnished with lime.

As this agent which characterizes living bodies does not appear to act according to the principles of chemistry, any inquiry into its nature would be foreign to the subject of this work. Physiologists have given it the name of the *living* or *animal* principle; and to them I beg leave to refer the reader.

Besides the different organs of the body, the blood is also employed in forming all the different secretions which are necessary for the purposes of the animal economy. These have been enumerated in a former part of this work. The process is similar to that of assimilation, and undoubtedly the agents in both cases are the same; but we are equally ignorant of the precise manner in which secretion is performed as we are of assimilation.

After these functions have gone on for a certain time, which is longer or shorter according to the nature of the animal, the body gradually decays, at last all its functions cease completely, and the animal dies. The cause of this must appear very extraordinary, when we consider the power which the animal has of renewing decayed parts; for it cannot be doubted that death proceeds, in most cases at least, from the body becoming incapable of performing its functions. But if we consider that this power is limited, and that it must cease altogether when those parts of

the system begin to decay which are employed in preparing materials for future assimilation, our surprise will, in some measure, cease. It is in these parts, in the organs of digestion and assimilation, accordingly, that this decay usually proves fatal. The decay in other parts destroys life only when the waste is so rapid that it does not admit of repair.

What the reason is that the decay of the organs causes death, or, which is the same thing, causes the living principle either to cease to act, or to leave the body altogether, it is perfectly impossible to say, because we know too little of the nature of the living principle, and of the manner in which it is connected with the body. The last is evidently above the human understanding; but many of the properties of the living principle have been discovered: and were the facts already known properly arranged, and such general conclusions drawn from them as their connection with each other fully warrant, a degree of light would be thrown upon the animal economy, which those who have not attended to the subject are not aware of.

No sooner is the animal dead, than the chemical and mechanical agents, which were formerly servants, usurp the supreme power, and soon decompose and destroy that very body which had been in a great measure reared by their means.

APPENDIX.

No. I.

OF THE MODE OF ANALYZING ORGANIC BODIES.

THE constituents of the greater number of organic bodies are carbon, hydrogen, azote, and oxygen. In animal bodies usually all the four exist together; but in many vegetable bodies, as acids, alcohols, sugars, starch, and gum, only hydrogen, carbon, and oxygen are to be found. Now to analyze an organic body is to determine with accuracy the weight of the carbon, hydrogen, azote, and oxygen, respectively, of which it is composed.

The method of performing this analysis was first contrived by Gay-Lussac, and Thenard, in the year 1811.* They first intimately mixed the substance to be analyzed with about twice as much dry and fused chlorate of potash as was necessary to burn it completely. This mixture was made up into small round balls about half the size of a pea. They were dried at the temperature of 212°, and the exact quantity of chlorate of potash and of the substance to be analyzed, contained in them was accurately determined. These balls were dropped one after another into a stout glass tube shut at its lower extremity, and having a stop-cock cemented into its upper extremity. This stop-cock had no hole, so that it might be turned quite round without opening any communication between the external air and the inside of the tube; but there was a cavity in it into which the balls could be put, and when the cock was turned round each ball dropped in succession to the bottom of the stout tube. From this perpendicular tube a small horizontal tube, soldered by the blowpipe, proceeded, dipped into a mercurial trough, to convey the gas evolved during the combustion into graduated flasks filled with mercury, and ready to receive it. The bottom of the tube being heated to a dull red heat, balls were dropped in suc-

* Recherches Physico-Chimiques, ii. 265.

cessively. Each burnt brilliantly, and a good deal of gas was evolved which passed into the mercurial trough. This process was continued till all the common air was driven out of the tube, and it was filled with nothing but the gas extricated by the combustion of the balls. A number of the balls (first accurately weighed) were then dropped into the tube and deflagrated, and the gas evolved collected in a graduated jar. Then another and another jar was filled in exactly the same manner, each containing the gas evolved by the combustion of nine or ten grains of the substance to be analyzed. The bulk of the gas in the first jar, being measured it was subjected to analysis, and consisted of a mixture of oxygen, carbonic acid, and azotic gas, (if the substance under examination contained that principle.) The bulk of the carbonic acid was determined by absorbing it by means of caustic potash, and that of the oxygen by mixing 100 volumes of it with 40 of hydrogen, and passing an electric spark through it. The diminution of volume determined the purity of the oxygen and the presence or absence of azotic gas, carbonic oxide, &c. The quantity of oxygen gas evolved from the weight of chlorate of potash used being known, and the quantity collected and in the state of carbonic acid gas being subtracted from it, the remainder indicated the volume of oxygen gas which went to the formation of water. The carbonic acid, hydrogen, and azote thus evolved by the combustion of the substance under analysis being known, and the amount of these being added and subtracted from the weight of the substance subjected to analysis, the remainder gave the quantity of oxygen which the substance under analysis contained.

In this way they analyzed fifteen vegetable substances, none of which contained azote, and four animal substances, each containing azote as a constituent.

The process of Gay-Lussac and Thenard was considerably improved by Berzelius in 1814.* He adopted the chlorate of potash, which he mixed with the substance to be analyzed. The mixture he put into a stout glass tube, shut at one end. The open end was luted to a small receiver, which terminated in a long glass tube filled with dry chloride of calcium. To the end of this tube was luted a bent tube, plunging into a mercurial trough with a glass jar filled with mercury to receive the gas evolved. After the process was over the receiver and chloride

* Annals of Philosophy, 401.

of calcium tube being weighed gave the quantity of water evolved. The carbonic acid in the jar, over mercury, was absorbed by a small glass of potash exactly weighed. The increase of weight gave the quantity of carbonic acid evolved. The glass tube containing the matter to be analyzed was strengthened by a ribbon of tin plate wrapped round it, and it was heated to redness, beginning at the end next the receiver, and passing backwards to the lower extremities.

The determining of the water and carbonic acid by weighing was a considerable improvement upon the process of Gay-Lussac and Thenard. But the apparatus was rather too complex, and the number of joinings too many. It would be difficult in this country, where our corks are bad, to make it always air-tight. Berzelius subjected from nine to ten grains of the substance under experiment to analysis. He analyzed thirteen vegetable substances, and as usual his results approached pretty near the truth.

About the year 1813, Gay-Lussac suggested to M. Chevreul the substitution of black oxide of copper for chlorate of potash in the analysis of vegetable and animal substances.* M. Gay-Lussac had employed this substitute in his analysis of the compounds of cyanogen.† In 1816, the use of it was highly commended by Dobereiner,‡ who does not seem to have been aware of its previous employment in organic analyses in France; at least he takes no notice of it.

In 1827, Dr Prout published in the Philosophical Transactions a memoir entitled *On the Ultimate Composition of Simple Alimentary Substances.*§ He had been occupied with these analyses for many years, had tried all the different methods of analysis recommended by preceding experimenters, and had found them all attended with difficulties that prevented him from attaining the requisite degree of accuracy. This induced him to have recourse to the combustion of the substances to be analyzed in a tube filled with oxygen gas. The matter to be analyzed was mixed with the requisite quantity of oxide of copper. It was then introduced into the tube. The apparatus was filled with the requisite volume of oxygen gas, the heat of a lamp was applied to the tube contain-

* Ann. de Chim. xcvi. 53.
† Ibid. xcv. 154, 184, 187.
‡ Schweigger's Jour. xvii. 369.
§ Phil. Trans. 1827, p. 385.

ing the mixture of oxide of copper and the body to be analyzed, and the oxygen gas was driven backwards and forwards through it, till the combustion was at an end, and till the oxide of copper, partially reduced, had recovered its original quantity of oxygen. The apparatus was then allowed to cool. The oxide of copper will imbibe all the moisture and air which it contained before the experiment began. The volume of gas in the tube is now measured with accuracy. If it is unaltered it follows that the oxygen and hydrogen in the body analyzed are in the proportion to form water. The volume of carbonic acid gas is then ascertained from which the weight of carbon is easily deduced. Subtracting this from the original weight of the substance under analysis, the remainder is the hydrogen and oxygen in the proportion which constitutes water.

If the volume of gas be increased it is a proof that the oxygen in the substance analyzed is more than what is necessary to convert the hydrogen into water; and the increase of volume gives the additional quantity of oxygen present.

If the volume be diminished it indicates that the hydrogen in the substance under analysis is more than what is requisite to convert the oxygen into water. And twice the volume of diminution gives the volume of hydrogen thus in excess.

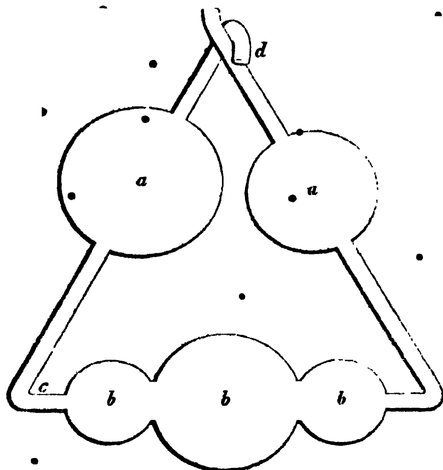
This method is susceptible of great accuracy. But it requires much accuracy in measuring the volumes of oxygen gas and carbonic acid gas evolved. And as the weight of the carbon, and even of the hydrogen, is deduced from the volume, it is necessary for accuracy that the specific gravity of these gases should be correctly known.

By this process Dr Prout analyzed twenty-one vegetable substances (all without azote), and the result in his hands was exceedingly near the truth. But the complexity of his apparatus, and the difficulties attending minute measurement of the volumes of the gases employed or formed, have prevented other chemists from following his method. We do not know, therefore, how it would succeed in the hands of chemists less cautious and scrupulously accurate than Dr Prout.

The attention of Professor Liebig to the analysis of organic substances seems to have been drawn by this memoir of Dr Prout. In 1830, he published a critical examination of Dr Prout's apparatus, pointed out its inapplicability to the analysis of substances

containing azote, and states several other objections to which it is unnecessary to refer. *

In 1831, Liebig† made known an apparatus which he had contrived, and which greatly facilitated the determination of the weight of carbonic acid gas formed during the analysis of organic bodies. The water formed was determined, as Berzelius had done, by causing the products of the combustion to pass through a tube filled with fragments of chloride of calcium. The increase of weight gave the water evolved. The contrivance for collecting the carbonic acid was a glass tube upon which were blown



the two large bulbs *a*, *a*, and the three small intermediate bulbs *b*, *b*, *b*, the capacity of all the three being only equal to that of one bulb *a*. The bulbs *b*, *b*, *b*, are filled to the line *c*, with a saturated solution of caustic potash, and the whole tube with its contents, after being accurately weighed, is luted by the extremity *d* to the tube containing the chloride of calcium. The glass tube containing the mixture of oxide of copper and the substance to be analyzed, after being repeatedly exhausted by means of a syringe attached to it, passing through a tube filled with chloride of calcium to get rid of moisture, is luted to the other extremity of the tube containing the chloride of calcium, and placed horizontally on a small iron grate, and heated gradually and slowly by means of ignited charcoal, and this is continued till the process is finished, which, if properly conducted, will occupy about two hours. The increase of weight in the chloride of cal-

* Poggendorf's Annalen, xviii. p. 357. † Ibid xxi. 1.

cium gives the quantity of water formed, and the increase of weight in the potash tube gives the quantity of carbonic acid formed. From these two it is easy to calculate the weight of hydrogen and carbon in the substances under analysis. For the hydrogen is one-ninth of the weight of the water, and the carbon three-elevenths of that of the carbonic acid.

Professor Liebig in the same paper showed how an estimate might be formed of the quantity of azote contained in the substance to be analyzed by subjecting it to a second analysis, in which the tube with the potash was left out, and the mixture of azotic and carbonic acid formed received in a set of ten or twelve graduated tubes filled with mercury, and standing on the mercurial trough. The ratio of the carbonic acid and azotic gas in each is determined by absorbing the carbonic acid gas; and that ratio gives the ratio of the atoms of azote and carbon. Suppose one volume azote and four volumes carbon, then for every atom of azote there are four atoms carbon. From these data, knowing the specific gravities of azotic and carbonic acid gases, it is easy to deduce the weight of azote in the substance under analysis.

It was this apparatus of Liebig which gave popularity to organic chemistry. The mode of analysis appeared easy and simple. Liebig devoted his laboratory to organic investigations. His pupils increased in number, and he started a periodical work entitled *Annalen der Pharmacie*, in which the labours of his numerous pupils were consigned. Organic analyses increased in number, and almost every animal and vegetable principle was subjected to this important scrutiny. Facts were increased prodigiously, as will be evident to the most careless observer, if the contents of the two volumes regarding animal and vegetable substances be inspected.

But the defects of oxide of copper as a means of analysis, pointed out by Prout, especially its property of absorbing moisture and air with avidity, rendered it desirable that some substitute free from these defects should be discovered. Liebig pointed out a substitute in 1837 in chromate of lead, the employment of which was first tried by Mr Richardson.* It is prepared by precipitating a salt of lead by bichromate of potash. The precipitate is well-washed, dried, and melted in a Hessian crucible. It is then pulverized, and, being put into a stoppered bottle, is ready for use. This salt has the important property of neither absorb-

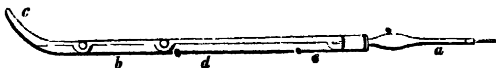
* Annalen der Pharm. xxiii. 58.

ing moisture nor air. Hence, when it is used, the water formed during the process may be determined with more accuracy than with oxide of copper. It gives out more oxygen than oxide of copper, and therefore admits a greater weight of the substance under analysis to be employed, which is of great consequence; for we cannot expect accurate results unless the quantity analyzed amount to fifteen or twenty grains.

In the fifth volume of Dumas' *Traité de Chimie appliquée aux Arts*, (p. 3), published in 1835, he has given a minute detail of the methods employed by him to secure accurate results when organic bodies are analyzed by means of oxide of copper. It will be worth while to state some of the most important of these methods, or checks, as they may be called.

The oxide of copper should not be prepared by precipitating a salt of copper by means of an alkali, because it has been ascertained that some of the alkali is apt to adhere to the oxide. We may obtain pure oxide of copper by heating turnings of that metal in a muffle till they are thoroughly oxydized, or by exposing acetate of copper to long-continued ignition in an open vessel. But one of the best sources of oxide of copper is the nitrate ignited in an open vessel. It gives a light, free, and very good oxide, but it should be well pounded and calcined a second time, in order to be sure that all the nitric acid has been driven off.

The glass-tube in which the combustion is made must be of crown-glass, that it may be heated to redness without melting. Its internal diameter should be about 0·4 inch, and its length not less than sixteen inches. One end should be shut and drawn out by the lamp into a fine point, *c*. The other end should be



smoothed by a file, to prevent it from injuring the cork to be fitted to it. The figure here given represents the combustion tube with the chloride of calcium tube *a* luted to it. About 1·5 inch at the bottom of the tube should be filled with oxide of copper. Then the mixture of oxide of copper and the substance to be analyzed occupying the space of several inches. The rest of the tube should be filled with oxide of copper. If the tube be quite filled with oxide of copper, the gas evolved by the combustion will force it out of the tube and spoil the analysis. Liebig gets over this difficulty by tapping the tube after filling it, so as

to leave a small empty space at the upper part of it through which the gas may flow without impediment. Dumas mixes the oxide of copper, and the mixture of oxide of copper, and the body under analysis, with copper turnings, along which the gas finds its way. Others insert in the axis of the tube a copper wire, along which the gas passes. Some one of these precautions seems necessary, yet they render the complete combustion of the substance under analysis more difficult. Should any carbonic oxide or carburetted hydrogen be mixed with the carbonic acid gas, it may make its way through the apparatus and be lost altogether. Hence it generally happens that the quantity of carbon obtained by such analyses is below the truth. In Liebig's laboratory, indeed, this error was in some measure compensated by estimating the atomic weight of carbon almost two per cent. too high. The true atomic weight of carbon is 0·75 ; but Liebig adopted Berzelius's number, 0·76435, which exceeds the truth by 1·913 per cent. The only sure way of burning the substance under analysis completely is Dr Prout's method of furnishing a supply of oxygen gas. Probably the mixture of the oxide of copper with a certain quantity of fused chlorate of potash, would answer the purpose ; or the length of that part of the tube filled with oxide of copper or chromate of lead might be considerably increased, and the whole might be kept at a red heat while the gas was made to pass very slowly through it. To prevent the tube from losing its shape it should be wrapt round with tinsel or a ribbon of sheet copper.

Great care is necessary in introducing the substance to be analyzed into the tube. If it be a solid it should be dried thoroughly at 212°, or at a higher temperature, if it will bear it without decomposition. A given weight should then be put into a dry warm porcelain mortar and triturated with nine or ten times its weight of oxide of copper or chromate of lead. It is then, while still warm, to be introduced into the tube. If the substance to be analyzed be very volatile, as camphor, naphthalin, &c., it is needless to triturate it with the oxide of copper. It is only necessary to introduce fragments of it into the tube alternating with oxide of copper till the requisite weight has been added, and then to proceed to analysis in the common way. When the liquid is volatile, but not exceedingly so, but boiling between 248° and 572°, it is to be put into a small tube shut at one end and open at the other. This tube is introduced into the decomposing

tube after some oxide of copper, and then the tube is filled with oxide of copper, and the analysis begun. When the substance to be analyzed is very volatile, as alcohol, ether, &c., it is introduced into a little glass bead, drawn out into a capillary point by the lamp. This bead is slipt into the decomposing tube, and covered in the usual way with oxide of copper, &c., and the analysis proceeded in.

When the substance to be analyzed contains azote, precautions are necessary to decompose certain compounds of azote which are apt to be formed. It may make its escape in the state of ammonia, or protoxide of azote, or deutoxide of azote. The ammonia will be decomposed into water and azotic gas in passing through the oxide of copper in a state of incandescence. The other two gases to be decomposed must be passed through a considerable length of red hot copper turnings. The oxygen of the gases combines with the copper, and the azote makes its escape and may be collected over mercury. In such cases the decomposing tube must be longer than ordinary, and must be divided into four compartments, the first filled with oxide of copper, the second with oxide of copper and the substances to be analyzed, the third with oxide of copper, and the fourth with copper turnings.

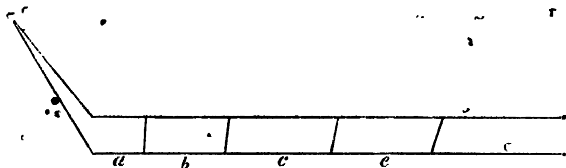
We must begin with heating to redness the extremity of the tube next the open end, and we must gradually bring the fire along the tube, and the whole copper turnings and oxide of copper must be red hot before we apply the heat to the mixture of oxide of copper and the substance to be analyzed. Care must be taken to keep the open extremity of the tube hot to prevent any accumulation of vapour there, which would prevent the success of the analysis.

We may form an idea of the success of the analysis by the appearance of the carbonic acid gas as it is condensed in the potash tube. If it comes over regularly and slowly, if it is quite colourless and without smell, we may conclude that our process is going on well. If, on the other hand, it be cloudy, coloured, and, above all, if any oily matter make its appearance in the tubes, we may conclude that the combustion of the matter under analysis is incomplete, and that portions of the carbon and hydrogen are making their escape in the form of oily vapour.

When an analysis is happily conducted the formation of gas ceases all at once. When carbon has escaped combustion, and

is mixed with the oxide of copper, the evolution of gas goes on for a long time. In such cases we should always mistrust the accuracy of our analysis.

M. Dumas's method of determining the quantity of azote in a body under analysis is somewhat different from that of Liebig, and when the combustion is complete (which, however, is difficult,) seems quite accurate. It will be worth while to state it here: Into the bottom of the decomposing tube some grammes of pure dry carbonate of lead are introduced. Above it, *b*, is put a mixture of oxide of copper and copper turnings. In *c* is



put a mixture of oxide of copper, and the body to be analyzed; in *e* ten or twelve grammes of oxide of copper mixed with some turnings; while the outer portion is filled with copper turnings. The tube is connected with a mercurial trough, exhausted, and then a portion of the carbonate of lead is heated. The carbonic acid evolved drives out the common air in the tube, taking its place, and the process is continued till pure carbonic acid passes into the mercurial trough, and is totally absorbed by the potash placed for the purpose. The whole portion *e* of the tube is then made red hot, and the portion *c* being gradually heated the azotic gas evolved is passed into the gas-holder over mercury. When it ceases to come over heat is applied to the rest of the carbonate of lead in *a*, which carries with it all the azotic gas remaining in the tube. The carbonic acid is absorbed by the potash, and nothing remains but the azotic gas. Its volume is measured, and its specific gravity being 0·9722, it is easy to determine its weight. This method is very good; but another has been lately contrived by Drs Will and Varrentrapp, which will be stated below.

The hydrogen is determined by means of dry fused chloride of calcium, as first proposed by Berzelius. The mixture of oxide of copper and the substance under analysis is put into the combustion tube. This tube is luted, by means of an excellent cork, to a long tube filled with fragments of chloride of calcium, and this long tube is attached to a small air-pump, or rather syringe. The air is exhausted, and then allowed to flow back through the

tube filled with chloride of calcium, which renders it very dry. The exhaustion being repeated in this way fifteen or twenty times, the moisture which the oxide of copper so readily imbibes is withdrawn, and the whole made dry. The decomposition is then begun and completed in the way already explained. The increase of weight of the chloride of calcium tube gives the quantity of water formed, and the ninth part of the weight of water is the amount of hydrogen contained in the substance under analysis. In general, the weight of hydrogen obtained exceeds a little that of the hydrogen in the substance under analysis. That is the consequence of the difficulty of depriving the oxide of copper of all moisture. The excess is so much less when chromate of lead is used: indeed, if the proper precautions be used, the error in that case may be considered as evanescent. The whole water is not absorbed by the chloride of calcium, a portion of it is usually deposited in a liquid state in the small bulb at the end of the chloride of calcium tube next the decomposing tube.

As common cork imbibes moisture it cannot be used when we wish to determine the hydrogen with very great accuracy. In that case, the tubes should be ground into each other so as to be air-tight.

Liebig's potash tube answers so well for determining the carbon by the weight of the carbonic acid evolved, that no additional observations in that subject seem necessary.

Liebig's method of determining the azote is somewhat different from that described above, which is the method of Dumas. He puts into the bottom of the decomposing tube a quantity of hydrate of lime ; and after the combustion is at an end, the hydrate of lime is heated, and its water converted into steam, which forces all the gas remaining in the apparatus into the gas tubes standing over mercury. These are filled in succession, and the ratio between the volume of carbonic acid and azotic gas being determined, it is easy to calculate how much azote the substance under analysis contained.

But it must be acknowledged that both the process of Dumas and of Liebig leaves considerable uncertainty, and that they afford at best only approximations to the truth. A new method has been recently proposed by Drs Varrentrapp and Will, which is both of easier execution, and promises to be susceptible of greater accuracy than any of the old methods.*

* Ann. der Pharm. xxxix. 257.

It is founded upon the great affinity which exists between azote and hydrogen. Whenever any substance containing azote and hydrogen is heated in contact with potash, lime, barytes, &c. it always gives out ammonia. Now ammonia is a compound of $Az H^3$. Almost every organic body containing azote contains also hydrogen; and the quantity of hydrogen is always sufficient for converting the azote into ammonia. This conversion always takes place. Hence we may determine the quantity of azote in any substance, by ascertaining the weight of ammonia, which it gives out when decomposed. Such is the basis of the method of Varrentrapp and Will.

Guy-Lussac has shown, that, if hydrate of potash be mixed with an organic body destitute of azote, the water of the hydrate is decomposed; its oxygen uniting with the carbon and hydrogen of the organic body, while its hydrogen is disengaged in the state of gas. The products formed by this energetic process of oxydizement vary according to the temperature to which the mixture is exposed, and according to the constitution of the organic body. It is enough to state here, that when the organic body is destitute of azote, hydrogen gas is disengaged. When the organic body contains azote, this free hydrogen unites with the whole of that azote, and is converted into ammonia. This process has been long in use to ascertain whether an organic body contains azote or not.

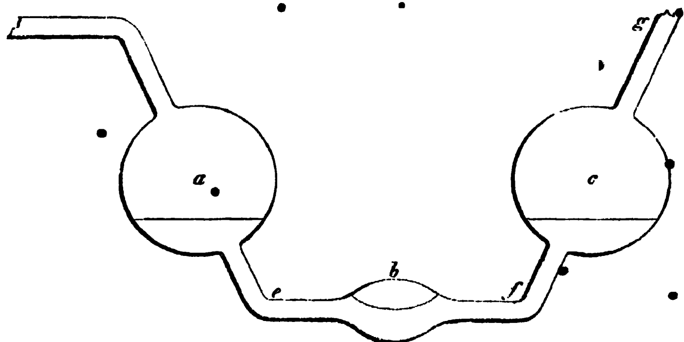
When a substance contains a great deal of azote, as uric acid, melamin, mellon, &c., it is natural to suppose that the whole azote may not be converted into ammonia. A portion of it may unite with part of the carbon of the substance, and form cyanogen, and this cyanogen (as also cyanic acid) may unite with the alkali or its bases. And as such a combination may resist decomposition at a high temperature, we may conjecture that a portion of the azote may be retained, and not make its appearance in the state of ammonia.

But Drs Varentrapp and Will have ascertained by direct experiment that when a sufficient quantity of hydrate of potash is employed, and when the heat is not too low, the whole azote, even in the compounds just mentioned, is converted into ammonia. When cyanodide of potassium, cyanate of potash, or paracyanic acid is heated to redness with an excess of hydrate of potash, or with a mixture of hydrate of potash or soda, with caustic lime, an abundant evolution of ammonia takes place, and in the residue,

no trace of cyanogen or of any of its compounds can be discovered. In such experiments it is necessary to employ so much alkaline hydrate, that the whole carbon of the matter be oxydized by the oxygen of the water of the hydrate. The mixture in the decomposing tube, after the process is finished, must be quite white. In proportion to the richness of the organic body in carbon, and according to the temperature, there are given out along with the ammoniacal gas other permanent gases, as the gas of marshes, hydrogen gas, olefiant gas, or a mixture of these, and in many cases liquid compounds of carbon and hydrogen, or at least drops of oily matter.

To the bodies richest in azote belong melamin, mellon, cyanogen, and its compounds. But they all contain as much of (or more) carbon in proportion to their azote, as is sufficient by its oxydizement to set free a sufficient quantity of hydrogen to convert the whole azote into ammonia. In some of these compounds, as mellon, whose formula is C^6 Az^4, and melamin, which is C^6 H^6 Az^6, the decomposition, when a sufficient quantity of alkaline hydrate is employed, goes on and is completed without the evolution of any permanent gas. All the carbon is converted into carbonic acid, which remains combined with the alkali, while all the azote is converted into ammonia, which flies off in the state of gas, but is absorbed by the muriatic acid placed in the tube to collect it.

The process employed by Varrentrapp and Will for collecting the ammonia from the decomposition of bodies containing azote is founded upon the facts that have been just stated. The organic body is mixed with a sufficient quantity of hydrate of potash or hydrate of soda, previously mixed with caustic lime. It is put into a crown glass tube from 16 to 18 inches long, and about 3



lines wide. The shut end is to be drawn out into a long point, which is hermetically sealed. To the open end of this tube is fixed, by means of a good cork, so as to be air-tight, the bent tube, *a, b, c*, somewhat resembling Liebig's potash tube; but having only the three bulbs, *a, b, c*. The central bulb, *b*, is filled with a quantity of muriatic acid of commerce to absorb the ammonia. The avidity of muriatic acid for ammonia is so great that there is no risk of any loss."

The hydrate of potash or soda is to be mixed with so much quicklime, that the whole can be easily reduced to powder, and that it should not melt, but only soften a little in the decomposing tube. As hydrate of soda has a smaller atomic weight than hydrate of potash, it is to be preferred. One part of hydrate of soda mixed with two parts of anhydrous lime will answer. When hydrate of potash is used, it should be mixed with thrice its weight of quicklime. The best way is to heat the hydrate of alkali to redness, so as to bring it into a state of fusion. It ought, then, to be rapidly pounded in a warm mortar, and intimately mixed with the lime. And while still dry, it must be put into a well-stoppered phial and kept for use.

The decomposing tube is now about half-filled with this mixture. The quantity of the organic body containing azote requisite varies with the quantity of azote which it contains. According to Varrentrapp and Will, it is not necessary to use more than six or less than three grains. It is to be mixed with the hydrate of soda and lime in a warm and dry mortar, and considerable precautions are necessary to prevent any loss.

The muriatic acid tube is attached to the decomposing tube by a good cork; and care must be taken to ascertain that the apparatus is air-tight. The open end of the tube, which contains no organic matter, is first to be heated to redness, in order to prevent any of the organic matter from passing without being decomposed completely. The cork must be kept as warm as possible, that no moisture may lodge about it; because such a deposition would cause a loss of azote by absorbing some ammonia.

As soon as the open end is red hot, the fire is removed farther back. The oxygen of the alkaline hydrate forms carbonic acid with the whole or with a portion of the carbon in the organic body, while the hydrogen combines with the azote and forms am-

monia, which escapes in the gaseous form. At the same time there escapes, (according to the nature of the organic substance,) either pure hydrogen gas, or carburetted hydrogen, which are not absorbed by the acid, and which are easily recognized by burning them with oxygen gas.

The combustion goes on so rapidly, that a constant current of gas passes off. But there is no risk of any of the ammonia escaping; it is absorbed so rapidly and so completely by the muriatic acid. When the action of the fire is suddenly stopped, the whole acid liquor gets into the ball *a*, and it may even (unless care be taken) make its way into the decomposing tube, and destroy the analysis.

But few substances contain so much azote, that, in order to convert the carbon into carbonic acid, the whole hydrogen set free combines with the azote into ammonia.

To prevent the too rapid absorption of the ammonia, Varrentrapp and Will recommended mixing those substances which contain a great deal of azote, with sugar or some organic body destitute of azote. This last substance, by its decomposition by means of the alkaline hydrate, gives out a permanent gas, which dilutes the ammoniacal gas, and prevents its too rapid absorption.

When the process is at an end, and this is known by the ceasing of the evolution of all gas, and by the substance in the decomposing tube being quite white, the point *a* of the decomposing tube is to be broken off, and air slowly sucked through the apparatus by applying the mouth to the extremity *g*. The object of this is to extract any ammonia that may remain and cause it to be absorbed by the muriatic acid.

The ammonia, while in contact with alcohol and charcoal in the decomposing tube, might form cyanogen or cyanodide of potassium. The white appearance of the residue in the decomposing tube is a proof that the heat has been sufficient to burn all the carbon, and that the formation of cyanogen is not to be dreaded.

Such is the mode of analysis of solid bodies containing azote. The number of organic liquids containing azote is small. The process for analyzing them is quite similar. A portion of the decomposing tube is filled with the mixture of alkaline hydrate and lime, then the glass globule containing the liquid to be analyzed is dropt in, and the tube is filled with mixture of alkaline hydrate and lime. The process of decomposition is the same as before.

After the process is completed, the liquid in the muriatic acid tube is emptied into a porcelain basin, and the tube is to be washed quite clean with a mixture of alcohol and ether. About an ounce or an ounce and a half is sufficient to wash out all the sal-ammoniac which is left in it. An excess of chloride of platinum is now added to it, and the whole is evaporated to dryness over the water-bath. If the process has been rightly conducted, the ammonia-chloride obtained has a fine yellow colour. When the organic body decomposed contained much carbon, and was difficult to burn, the platinum precipitate has a darker colour, because the muriatic acid being evaporated in contact with carburetted hydrogen blackens. But this has no influence on the result, provided the chloride be carefully washed.

The dry residue in the porcelain dish when cold is to be treated with a mixture of two volumes of strong alcohol and one volume of ether, in which the platinum sal-ammoniac is quite insoluble, though the chloride of platinum dissolves in it readily. We easily know by the yellow colour of the solution if an excess of chloride of platinum has been employed. If the solution be colourless, it follows that too little of that chloride has been employed.

The platinum sal-ammoniac must be collected on a filter, dried, and washed with alcohol and ether till these liquids pass through colourless. It is then to be dried at 212°, and weighed. It is a compound of one atom of bichloride of platinum and one atom of chloride of ammonium. Bichloride of platinum is $Pl\ Chl^2 = 21$, and chloride of ammonium is $Az\ H^4 + Chl = 6{\cdot}75$, so that 27·75 grains of it contain 1·75 of azote. Hence, if we multiply the ammonia-bichloride of platinum obtained by 14, and divide the product by 222, the quotient will give the weight of azote which it contains. If we expose this yellow powder to a good red heat, everything will be driven off except the platinum. Now, 27·75 of the salt leave 12 of platinum. Hence, if we heat to redness, and weigh the residue, every 12 grains is equivalent to 1·75 grains of azote. If, therefore, we multiply the weight of platinum powder obtained by 1·75, and divide the product by 12, the quotient will give the weight of azote in the quantity of organic matter subjected to analysis.

From the experiments of Varrentrapp and Will, it appears that

this process does not answer when the body analyzed contains azote in the form of nitric acid, not even when mixed with six times its weight of sugar. Indeed, the late experiments of M. Reiset have shown that the process of Varrentrapp and Will is not susceptible of absolute accuracy. When bodies destitute of azote, as sugar and stearin, are heated in a combustion tube with a mixture of lime and hydrate of soda, a certain portion of ammonia always makes its appearance, derived from the azote of the common air contained in the tube. This azote first unites with carbon, and forms cyanogen, and the cyanogen is ultimately converted into ammonia. Sugar treated in this way gave 1·03 per cent. and stearin 0·92 per cent. of ammonia. The error from this source in the eighteen analyses made by Varrentrapp and Will, namely, of urea, uric acid, taurin, oxamide, caffein, asparagin, melamin, hippuric acid, amygdalin, narcotin, piperin, brucin, harmalin, fibrin, albumen, and casein, protein and oil of mustard was exceedingly small. But if Manzini's analysis of cinchovina be correct, that it contains 7·18 per cent. of azote, the error, when the azote is determined by mixing it with sugar, and collecting the ammonia formed, is so great that the azote is increased from 7·18 to 11·95, or 4·77 per cent.*

Such are the methods of determining the carbon, hydrogen, and azote contained in organic bodies. These being added together, and the sum subtracted from the weight of the organic body subjected to analysis, the remainder must represent the weight of oxygen which the body contains; but which, from the way in which the carbon and hydrogen are obtained, united to oxygen, cannot be evolved in a separate state.

Having obtained the weight of each constituent in 100 parts of the organic body subjected to analysis, the next step is to determine the number of atoms of each ingredient contained in an integrant particle of the organic body. To determine this we must know the atomic weight of the body under examination. Now this body may be an acid, or a base, or a volatile neutral body, or a fixed volatile body.

1. To determine the atomic weight of an acid we must, in the first place, ascertain how much water it contains when in crystals, how much of this water can be driven off by the highest temperature which it can bear without decomposition, and how

* Ann. de Chim. et de Phys. (3d series), v. 469.

much more it loses when strongly heated with a given weight of oxide of lead. Suppose we have 7·875 of oxalic acid crystals. If we expose these crystals to the highest temperature they can bear, without decomposition, the loss of weight will be 2·25, which is equivalent to two atoms water. If we mix the 5·625 of residue with fourteen yellow oxide of lead, and heat, the loss of weight will be 1·125, which is equivalent to another atom of water, and there will remain a neutral compound of fourteen oxide of lead, and 4·5 oxalic acid. But fourteen is an atom of oxide of lead, consequently 4·5 is an atom of anhydrous oxalic acid. Now, as oxalic acid is a compound of,

Carbon, . .	33·33
Oxygen, . .	66·66

It is obvious that it must be composed of,

2 atoms carbon, . .	1·5
3 atoms oxygen, . .	3·
	4·5

Because this number of atoms alone gives the ratios and the atomic weight of the acid.

As another example let us take 26·25 of crystals of citric acid, and heat them sufficiently. The water driven off will weigh 2·25. If we mix the residual 24 with 42, or any greater quantity of oxide of lead, and heat in a crucible, taking care not to decompose the acid, there will remain 62·625. From this, if we subtract 42, the weight of the oxide of lead, there will remain 20·625 for the weight of the anhydrous acid. The loss of weight, consequently, is 3·375, which represents 3 atoms of water. These three atoms of water have been replaced by 42, or three atoms of oxide of lead. Hence, citric acid is tribasic, and its atomic weight in the anhydrous state must be 20·625. It is composed of,

Carbon, . .	43·636
Hydrogen, . .	3·030
Oxygen, . .	53·334
	100

Hence the number of atoms in it must be,

12 carbon,	= 9
5 hydrogen,	= 0·625
11 oxygen,	= 11·
	20·625

Because this is the number that gives the atomic weight, and the ratio of the constituents.

From these examples it will be evident that, in order to have the atomic weight of an acid, we must be able to get it quite anhydrous. But in many cases we cannot drive off the whole of the water which it contains without substituting some other base. Now oxide of lead and oxide of silver are the two bases that answer best for obtaining anhydrous salts. Oxide of lead is most convenient because it is cheapest. We must determine the weight of water that escapes and the weight of oxide of lead which takes its place. These will bear a certain ratio to each other. If the water be 1·125 and the oxide of lead 14, then the acid is monobasic, and its atomic weight is obtained by simply analyzing its salt of lead, reckoning the weight of oxide of lead in it 14, and calculating the corresponding weight of the acid. If the water displaced be 2·25, and the oxide of lead substituted in its place 28, then the acid is bibasic, and so on.

What are called *ethers* are combinations of an atom of acid with an atom of $C^4 H^5 O$. A good way of determining the atomic weight of an organic acid is to convert it into ether and to analyze in the ordinary way the ether obtained. Being composed of an atom of acid and an atom of $C^4 H^5 O$, it is easy from that analysis to deduce the atomic weight of the acid.

The mode of determining the atomic weight of bases is so nearly the same with that of acids that but few remarks are necessary. A given weight of the base dried at 248°, may be dissolved in alcohol. The solution may be mixed with water and the alcohol distilled off. We may then exactly neutralize the base with sulphuric acid, and, by decomposing afterwards by chloride of barium, determine the weight of sulphuric acid capable of saturating a given weight of base. This (if we suppose an atom of base to saturate an atom of acid) gives us data for calculating the atomic weight of the base.

Liebig employs another method, which often answers very well. It consists in causing a current of dry muriatic acid gas to pass through a glass tube blown into a ball in which a weighed quantity of the base is placed. The increase of weight gives the quantity of muriatic acid which has united to the base, and enables us to calculate the atomic weight of that base. The muri-

atic gas is dried by passing through a tube filled with chloride of calcium.

When neutral bodies, which do not enter into definite compounds with other substances, are volatile, as the volatile oils, Dumas has pointed out a very ingenious method of determining their atomic weight by the density of their vapour. He puts into a glass balloon a quantity of the substance, the density of which is to be determined, and then draws out the mouth of the balloon to a capillary point that it may be easily hermetically sealed. The balloon is then heated from 70° to 100° above the boiling point of the substance, whose specific gravity is to be determined, and it is kept at that temperature till all the excess of the substance is driven out of the balloon. When this has taken place the capillary end of the mouth is hermetically sealed. The vessel is now filled with vapour at a known temperature, under the pressure of the atmosphere at the instant that the balloon was shut. The volume of the balloon and the weight of matter contained in it being known we have all the necessary data for determining the specific gravity of the vapour.

The balloon or globular glass vessel should be of clear glass, equal and not too thick. Its capacity should not be less than fifteen nor more than thirty cubic inches. It must be washed clean in the inside, and dried by passing a current of air through it while hot. The mouth must then be drawn out into a long capillary tube. The air which it contains is dried by putting the balloon under the receiver of an air pump, exhausting the receiver, and causing the air to return into the receiver through a tube filled with dry chloride of calcium. By repeating the exhaustion two or three times the air in the balloon will be quite dry. The balloon is then weighed, marking the height of the thermometer and barometer at the time.

If the substance, the density of whose vapour is to be taken, acts on the air of the atmosphere, we must fill the balloon with hydrogen or carbonic acid gas.

The balloon is now to be gently heated, and the beak of it plunged into the substance, the specific gravity of whose vapour is to be determined, which is supposed to be either liquid or to be liquefied by a moderate heat. In proportion as the balloon cools the substance enters into it. We should allow about 80 grains of it to enter.

When we operate on a substance that boils at 212° or at a higher temperature, its introduction into the balloon is attended with no difficulty. But if it be very volatile, as soon as it comes into the balloon it gives out much vapour, stops the process, or even drives out again the portion which has entered. To remedy this the balloon is sprinkled with ether, and we blow upon it with a bellows to hasten the evaporation. This cools the balloon, and allows the process to proceed; on the other hand, when we operate upon a substance whose melting point is a little elevated, it becomes solid in the capillary tube and stops the process. To remedy this we take up the balloon with a pair of pincers, and hold it over a charcoal fire, so that the temperature of the capillary portion is heated. If we now plunge the capillary point into the substance it passes in without becoming solid.

The balloon being thus charged it is put into the bath in which the experiment is to be conducted. If the matter boils below 212°, the bath consists of water; if below 393° we employ a bath of fixed oil; if above 400°, the bath must consist of fusible metal. We might raise an oil bath to 572° or even to 600°; but we would run the risk of setting fire to the apartment. The experiment on that account would require to be performed out of doors. The bath should be such that it can be raised 100° above the boiling point of the liquid, the density of whose vapour we wish to determine. If attention is not paid to this the specific gravity of the vapour will be too high.

The liquid employed for the bath is put into a cast iron pot. The balloon is attached to an iron triangle, which is kept plunged into the liquid by three leaden weights attached to the ends of the triangle—a thermometer is plunged into the bath to indicate the temperature. The fire is lighted, and continued till the bath reaches the boiling point of the liquid in the balloon. Vapour then issues from the capillary beak, and continues till the whole is driven off, and nothing remains but vapour, with which the balloon is filled. We must continue the heat for some time after the evolution of vapour is at an end. The capillary end of the balloon is then hermetically sealed. To see whether the sealing is complete we have only to blow cold air on the beak of the balloon. The vapour condenses in the capillary tube into a liquid, but this does not happen if the sealing be not complete.

No farther precautions are necessary if the bath be water.

When an oil bath is used there is more difficulty in obtaining the same temperature in the vapour and the bath. When the oil bath is heated to within 20° or 30° of the point at which we wish to stop we must damp the fire. This causes the temperature to rise more slowly. When we are within 8° or 10° of the point the fire must be drawn. This causes the increase of temperature to be very slow, and enables that of the vapour to become as high as that of the oil.

The balloon is now removed from the bath, and wiped clean with the greatest care. When cold and clean it is weighed. The increase of weight gives the quantity of matter in the balloon that had been converted into vapour.

The beak is now plunged into mercury and the point broken off. The mercury enters the balloon and fills it completely, if the whole air had been expelled. If not, a portion of air remains, the volume of which must be noted and subtracted from the capacity of the balloon. When the experiment has been properly made the residue of air does not exceed 0·1 or 0·2 cubic inch.

The capacity of the balloon is determined by filling it with mercury, and measuring the mercury by pouring it into a graduated vessel. By these determinations we know the weight of the vapour and its bulk, from which we deduce the specific gravity. The excess of the weight of the balloon full of vapour, minus the weight of the air which the balloon contains, gives us the weight of the vapour.

Knowing the volume of the balloon and the temperature of the air when it was weighed, we bring this volume by calculation to what it would be, supposing the thermometer at 32° and the barometer at 30 inches, and this corrected volume is converted into weight, by the known weight of 100 cubic inches of air at 32°, and when the barometer stands at 30 inches; namely, 32·79 grains.

As the balloon was increased in bulk by the high temperature, we must calculate how much that was, and allow for it. This is easily done, as we know that the expansion of glass for 1° of Fahrenheit is $\frac{1}{72867}$. All these corrections being made we have the weight and the bulk of the vapour; and, dividing the latter by the former, the quotient gives us the specific gravity of the vapour under examination.

Now let us see how this knowledge of the specific gravity of

a vapour may be applied to the knowledge of its atomic weight, and consequently of the number of atoms which it contains. Let us take benzoic acid as an example. It is composed of,

Carbon,	74·34
Hydrogen,	4·42
Oxygen,	21·24
	100·00

The specific gravity of its vapour, as determined by Dumas and Mitcherlich, is 4·27. Now the specific gravity of a volume of carbon vapour and hydrogen gas, and of half a volume of oxygen gas* is as follows:

Carbon,	0·4166
Hydrogen,	0·0694
Oxygen,	0·5555

The atomic weight is 14·125. Now it is easy to see that C^{14} H^{5} O^{3} give that atomic weight. To see whether the specific gravity of the vapour of benzoic acid agrees with this number, we have,

14 volumes carbon weigh	5·8333
5 volumes hydrogen,	0·3472
$1\frac{1}{2}$ volume oxygen,	1·6666
	7·8472

If these 22 atoms were condensed into one volume the specific gravity of the vapour would be 7·8472. But this great condensation seldom takes place. In general we must divide by 2, showing that the atoms are condensed into two volumes in the vapour. Dividing 7·8472 by 2, we have 3·9236, which approaches pretty nearly to the density of the vapour found by experiment.

Let us take another example in which the atomic weight cannot be determined directly; that we may see the use that may be made of the specific gravity of the vapour. Let the substance be camphor. It is composed of,

Carbon,	78·94
Hydrogen,	10·53
Oxygen,	10·53
	100·00

* The reason of taking a volume of the first two and half-a-volume of oxygen, is, that a volume of carbon and a volume of hydrogen are each reckoned equivalent to an atom, while a volume of oxygen is equivalent to two atoms.

The specific gravity of its vapour, as determined by Dumas, is 5·337.

To obtain an idea of the number of atoms which it may contain, let us divide the constituents per cent. by the atomic weight of each constituent.

Carbon,	.	$\frac{78{\cdot}94}{{\cdot}75}$ =	105·25
Hydrogen,	.	$\frac{10{\cdot}53}{{\cdot}125}$ =	84·24
Oxygen,	.	$\frac{10{\cdot}53}{{\cdot}1}$ =	10·53

Hence the ratios of the respective atoms are, 105·25, 84·24, and 10·53. It will be convenient to bring these numbers to lower terms. And the simplest way is to suppose the oxygen only to amount to one atom. If we calculate on this supposition we find, that the constituents of camphor will be,

Carbon,	. .	9·995	atoms, or	10	atoms.
Hydrogen,	.	8·	do.	8	do.
Oxygen,	.	1·	do.	1	do.

Let us see how far the specific gravity of the vapour of camphor will agree with this estimate,

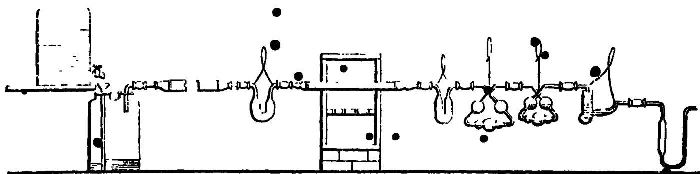
10 volumes carbon weigh,	4·1667
8 volumes hydrogen, .	0·5555
½ volume oxygen, .	0·5555
	5·2777

It gives us 5·2777 for the specific gravity, on the supposition that the 19 atoms are condensed into one volume. But, as in most organic vapours, the atoms are condensed, not into one, but into two volumes, it is much more probable that the constitution of camphor is C^{20} H^{16} O. The weight of these volumes would be 10·5555, which, divided by 2, would give 5·2777, differing but little from 5·337, found by Dumas.

These examples will give the reader a sufficient idea of the way in which the atomic weight is deduced from the knowledge of the specifie gravity of the vapour of a body whose constituents have been determined by analysis. This specific gravity ought to amount to half the weight of the atoms of which the vapour is composed. It must be acknowledged, however, that this mode of coming at the atomic weight is only conjectural: for we cannot assign any reason why the atoms making up the organic body constitute not one volume, or three or four volumes, but always two volumes. There doubtless is a reason for it, if the

supposition be correct; but at present it is out of our power to assign any reason whatever.

Such was the state of the analysis of organic bodies when M. Dumas, by an admirable series of experiments, demonstrated that the atomic weight of carbon, as admitted by the continental chemists, from the experiments of Berzelius, namely, 0·76438, is about 2 per cent. too high; and that the true number is 0·75.* To determine the exact composition of carbonic acid, MM. Dumas and Stas placed diamonds successively in a porcelain tube, which was heated to redness, and a current of oxygen gas passed through it till the diamond was converted into carbonic acid. The oxygen passed previously through a tube filled with fragments of pumice imbibed with caustic potash, and a second tube filled with fragments of caustic potash, to deprive the oxygen gas of every trace of carbonic acid with which it might happen to be mixed. It then passed through a tube filled with fragments of pumice impregnated with sulphuric acid, in order to deprive it of any water which it might contain. Beyond the porcelain tube was luted to it a long tube filled with oxide of copper, which was kept in a state of ignition during the process, and through which the surplus oxygen and the carbonic acid formed all passed. To this was luted a tube bent like U, and filled with fragments of pumice soaked in sulphuric acid, to imbibe any water that might be formed during the combustion; then a Liebig's tube containing caustic potash, then two tubes in U filled with pumice impregnated with caustic potash, and lastly, a tube in U filled with fragments of pumice impregnated with sulphuric acid, and finally, another tube containing potash in powder. The whole apparatus is represented in the figure below.



It was ascertained by preliminary trials that, in this appa-

* Ann. de Chim. et de Phys. (third series,) i. 5. These experiments have been repeated and confirmed by Erdmann and Marchant. Ibid. iii. p. 500.

ratus, the whole carbonic acid formed during the combustion of the diamonds was absorbed, and could be determined by weighing the several parts of the apparatus.

1471 parts of graphite being burned in this apparatus, the carbonic acid formed was found to weigh 5395. Hence it is composed of 2 oxygen + 0·7497 carbon.

The diamond is much more combustible than graphite. The quantity of hydrogen which it contained was not appreciable, and certainly did not amount to $\frac{1}{12000}$th of the weight of the diamond. The mean of five experiments on the combustion of the diamond, in which the greatest quantity of diamond burnt was 21·22 grains and the least 10·926, gave for the composition of the carbonic acid formed,

Oxygen, .	800·	or 2
Carbon, . . .	300·02	or 0·75005

It follows from these analyses of Dumas and Stas that the atomic weight of carbon adopted by Liebig and his pupils in the laboratory at Giessen is too high. Consequently, in all their analyses the quantity of carbon found by them in organic bodies is too high, and consequently the quantity of oxygen too low. Dumas has shown that in all these analyses a portion of the carbonic acid formed was allowed to escape. This partly compensated for the excess of carbon calculated, and brought their results very near the truth. This loss of carbon took place in four different ways.

1. The carbon is not completely consumed from the want of oxygen.

2. The copper reduced is partly converted into carburet of copper.

3. The liquid potash in Liebig's tube allows some of the carbonic acid formed to escape.

4. The air sucked through the apparatus carries off water from the potash, and diminishes its weight.

These observations of Dumas leave no doubt that organic analysis, in its present state, is incapable of giving results, the accuracy of which can be fully depended on. To bring it to the requisite state of precision he proposes the following amendments:

1. The quantity of organic matter analyzed should never be less than 15 or 20 grains.

2. After the analysis is terminated, but while the decompos-

ing tube is still red hot, a considerable quantity of oxygen gas should be passed through it, so as to burn all the charcoal deposited, and to re-oxydize the copper, which has been reduced during the process.

3. To collect all the water, besides a tube filled with chloride of calcium, there should be another filled with pumice, charged with sulphuric acid.

4. To collect all the carbonic acid gas, besides Liebig's potash tube, there ought to be another filled with fragments of dry potash, and another with fragments of pumice, charged with liquid potash. The dry potash arrests the water with which the carbonic acid may be charged, in consequence of its passing through the liquid potash in Liebig's tube.

After the oxygen gas has completed the combustion, and the whole has been allowed to cool, a quantity of dry air is to be passed through the apparatus to displace the oxygen gas, and prevent any augmentation of weight which might otherwise ensue.

The analysis should be made slowly, and ought to occupy several hours.

Thus Dumas' process of analysis is the same as that of Dr Prout, with some improvements, which enable him to weigh the water and the carbonic acid formed. When rightly conducted the results must be accurate, and of course, however often repeated, the same proportion of constituents must be obtained. But Dumas' process enables us only to determine the weight of carbon and hydrogen contained in the organic body analyzed. When that body contains azote we must have recourse to the process of Varrentrapp and Will, which has been already described.

No. II.

Table of the Atomic Weights of Animal Substances and of the Vegetable Substances which have been investigated by Chemists during the years 1839, 1840, 1841, and 1842, oxygen being unity.

	Composition.	Atomic weight.
A		
Abies excelsa resin, *a* .	$C^{40}H^{29}O^{6}$	39·625
Abies excelsa resin, *b* .	$C^{40}H^{29}O^{5}$	38·625
Acetate of oxide of amyle	$C^{4}H^{3}O^{3}+C^{10}H^{11}O$	16·25
Acetate of methyle .	$C^{4}H^{3}O^{3}+C^{2}H^{3}O$	9·25
Acetic acid . .	$C^{4}H^{3}O^{3}$	6·375
Aconitic acid . .	$C^{8}H^{4}O^{8}$	14·5
Adipic acid . .	$C^{14}H^{9}O^{7}$	18·625
Albumen . . .	$10(C^{40}H^{31}Az^{5}O^{12})+Ph+S^{2}$	552·25
Albumen of silk . .	$C^{54}H^{44}Az^{7}O^{19}$	77·25
Alcohol . . .	$C^{4}H^{5}O+HO$	5·75
Aldehyde . . .	$C^{4}H^{3}O+HO$	5·5
Allantoin . . .	$C^{4}H^{3}Az^{2}O^{3}$	9·875
Alloxane . . .	$C^{8}H^{4}Az^{2}O^{10}$	20·
Alloxanic acid . .	$C^{8}H^{2}Az^{2}O^{8}+2(HO)$	19.
Alloxantin . . .	$C^{8}H^{5}Az^{2}O^{10}$	20·125
Amarythrin . .	$C^{11}H^{6}O^{7}$	16·
Ambrein . . .	$C^{33}H^{32}O$	29·75
Amyle . . .	$C^{10}H^{11}$	8·875
Anemonic acid . .	$C^{7}H^{5}O^{6}$	11·875
Anemonin . .	$C^{7}H^{3}O^{4}$	9·625
Anilin . . .	$C^{12}H^{7}Az$	11·625
Animé resin . .	$C^{40}H^{32}+HO$	35·125
Anisic acid . .	$C^{16}H^{6}O^{5}$	17·75
Anisoin . . .	$C^{20}H^{12}O^{2}$	18·5

	Composition.	Atomic weight.
Anisol . . .	$C^{14}H^{7}O^{2}$	13·375
Anserin . . .	$C^{10}H^{9}O^{3}$	11·625
Anthracin . .	$C^{30}H^{12}$	24·
Anthranilic acid . .	$C^{14}H^{6}AzO^{3}$	16.
Antiar resin . .	$C^{40}H^{30}O^{2\frac{1}{2}}$	36·25
Anthracinase . .	$C^{30}H^{11}O$	24·875
Anthracinese . .	$C^{30}H^{10}O^{2}$	25·75
Anthracinise . .	$C^{30}H^{9}O^{3}$	26·625
Anthracinose . .	$C^{30}H^{8}O^{4}$	27·
Anthracinuse . .	$C^{30}H^{7}O^{5}$	28·375
Apoglucinic acid . .	$C^{18}H^{11}O^{10}$	24·875
Aspartic acid . . .	$C^{6}H^{5}AzO^{6}$	14·375
Asphaltene . .	$C^{19}H^{15}O^{3}$	19·125
Azalaic acid . .	$C^{10}H^{8}O^{4}$	12·5
Azobenzide . .	$C^{12}H^{5}Az+Aq$	12·5
Azobenzoid . .	$C^{42}H^{16\frac{1}{2}}Az^{2\frac{1}{2}}$	37·9375?
Azobenzoidin . .	$C^{84}H^{33}Az^{5}$	75·875
Azobenzolid . .	$C^{84}H^{33}Az^{5}$	75·875
Azotide of benzyle .	$C^{14}H^{5}Az$	12·875
Azo-erythrin . .	$C^{22}H^{19}AzO^{22}$	42·625
Azoleic acid . .	$C^{13}H^{13}O^{4}$	15·375
Azolitmin . .	$C^{17}H^{12}AzO^{10}$	26·?
Azomaric acid . .	$C^{20}H^{9}AzO^{6}+2(HO)$	24·375
B		
Bdellium . . .	$C^{40}H^{31}O^{5}$	38·875
Benzamide . .	$C^{14}H^{5}O^{2}+AzH^{2}$	15·125
Benzene . . .	$C^{12}H^{6}$	9·75
Benzhydramide . .	$C^{42}H^{18}Az^{2}$	37·25
Benzilic acid . .	$C^{28}H^{11}O^{5}+Aq$	28·5
Benzimide . .	$C^{28}H^{11}AzO^{4}$	28·125
Benzin . . .	$C^{12}H^{6}$	9·75
Benzoate of hydret of benzyle . .	$C^{14}H^{5}O^{3}+2(C^{14}H^{6}O^{2})+HO$	41·75
Benzoate of oxide of methyle . .	$C^{14}H^{5}O^{3}+C^{2}H^{3}O$	17·
Benzoene . . .	$C^{14}H^{8}$	11·5
Benzoic acid . .	$C^{14}H^{5}O^{3}$	14·125
Benzoin . . .	$C^{14}H^{6}O^{2}$	13·25
Benzoin resin, *a* . .	$C^{70}H^{42}O^{14}$	71·75
Benzoin resin, *b* . .	$C^{40}H^{42}O^{9}$	41·75
Benzoin resin, *c* . .	$C^{30}H^{20}O^{5}$	30·
Benzole . . .	$C^{12}H^{6}$	9·75
Benzolon . . .	$C^{11}H^{4}O$	9·75
Benzone . . .	$C^{13}H^{5}O$	11·375
Benzostilbin . .	$C^{31}H^{11}O^{2}$	26·625
Benzyle . . .	$C^{14}H^{5}O^{2}$	13·125
Benzylic acid . .	$C^{14}H^{5}O^{2}$	13·125
Betulin . . .	$C^{40}H^{33}O^{3}$	37·125

	Composition.	Atomic weight.
Bibromisatic acid .	$C^{16}H^{3}Br^{2}AzO^{4}+HO$	39·25
Bibromisatide . .	$C^{16}H^{4}Br^{2}AzO^{4}+S$	40·25
Bibromisatin . .	$C^{16}H^{3}Br^{2}AzO^{4}$	38·125
Bichlorisatic acid .	$C^{16}H^{3}Chl^{2}AzO^{4}+HO$	28·25
Bichlorisatin . .	$C^{16}H^{3}Chl^{2}AzO^{4}$	27·125
Binitrobenzide . .	$C^{14}H^{4}Az^{2}O^{8}$	22·5
Binitrobenzoene . .	$2(AzO^{4})+C^{14}H^{6}$	22·75
Bisulphate of amyle .	$C^{10}H^{11}O+2(SO^{3})+HO$	21·
Bisulphuret of ethyle	$C^{4}H^{5}S^{2}$	7·625
Botany Bay resin .	$C^{40}H^{20}O^{12}$	44·5
Bromasinol . .	$C^{20}H^{9}O^{2}+Br^{3}$	48·125
Bromide of amyle .	$C^{10}H^{11}O+Br$	19·875
Bromide of benzyle .	$C^{14}H^{5}O^{2}+Br$	23·125
Bromide of cacodyle .	$C^{14}H^{6}Az^{2}+Br$	23·25
Bromide of methyle .	$C^{2}H^{3}Br$	11·875
Bromide of salycyle .	$C^{14}H^{5}O^{4}Br$	25·125
Bromisatin . .	$C^{16}H^{4}BrAzO^{4}$	28·25
Bromobenzoic acid .	$2(C^{14}H^{6}O^{4})+HBr+2Aq$	41·375
Bromocuminol . .	$C^{20}H^{11}O^{2}Br$	28·375
Bromophenisic acid .	$C^{12}H^{2}Br^{3}O+HO$	41·375
Bruçina . . .	$C^{46}H^{26}Az^{2}O^{8}$	49·25
Butyric acid . .	$C^{8}H^{5}O^{3}$	9·625
C		
Cacodyle . . .	$C^{4}H^{6}Az^{2}$	13·25
Cacodylic acid . .	$C^{4}H^{6}Az^{2}O^{4}+HO$	18·375
Caffein . . .	$C^{12}H^{6}Az^{3}O^{3}$	18·
Campholic acid .	$C^{20}H^{17}O^{3}$	20·125
Camphoric acid .	$C^{10}H^{7}O^{3}$	11·375
Camphosulphuric acid .	$C^{20}H^{13}+S^{2}O^{5}$	25·625
Cancrin . . .	$C^{16}H^{13}O^{4}$	17·625
Cantharidin . .	$C^{10}H^{6}O^{4}$	12·25
Carbazotic acid . .	$C^{12}H^{3}Az^{3}O^{14}$	27·625
Carbomethylic acid .	$C^{2}O^{4}+C^{2}H^{3}O$	8·375
Carbovinic . .	$CO^{2}+C^{4}H^{5}O$	7·375
Carmin . . .	$C^{32}H^{24}AzO^{20}$	48·75
Casein . . .	$10(C^{40}H^{31}Az^{5}O^{12})+S$	548·25
Catechuic acid . .	$C^{20}H^{10}O^{9}$	25·25
Cedrene . . .	$C^{32}H^{24}$	27·
Cerebric acid . .	$3(C^{66}H^{63}AzO^{14})+Ph$	221·375
Cerosin . . .	$C^{48}H^{50}O^{2}$	44·25
Cetene . . .	$C^{100}H^{100}$	
Cinchonina . . .	$C^{40}H^{24}Az^{2}O^{2}$	38·5
Cinnamein . . .	$C^{54}H^{26}O^{8}$	51·75
Cinnamen . . .	$C^{16}H^{8}$	13·
Cinnamonic acid .	$C^{19}H^{7}O^{3}$	18·125
Cinnamonic ether .	$C^{18}H^{7}O^{3}+C^{4}H^{5}O$	22·
Citraconic acid . .	$C^{5}H^{2}O^{3}$	7·

	Composition.	Atomic weight.
Citric acid . .	$C^{12}H^5O^{11}$	20·625
Cocinic acid . .	$C^{27}H^{27}O^4$	27·625
Codeina . . .	$C^{35}H^{20}AzO^5$	35·5
Collin . . .	$C^{13}H^{10}AzO^5$	19·5
Colophony . . .	$C^{40}H^{30}O^4$	37·75
Comenic acid . .	$C^{12}H^2O^8+2(HO)$	19·5
Copal resin, *b* . .	$C^{40}H^{31}O^5$	36·875
Chelidonina . .	$C^{40}H^{20}Az^3O^6$	43·75
Chloracetic acid . .	$C^4Chl^3O^3+HO$	20·625
Chloranil . . .	$C^{12}Chl^2O^2$	20·
Chloranilic acid . .	$C^{12}HChlO^4+2(HO)$	17·625
Chloretheral . .	C^4H^4ChlO	9·
Chloride of acetate of oxide of methyle .	$C^4HChl^2O^3+C^2H^3O$	18·
Chloride of aldehyden .	$C^4H^3Chl^3$	16·875
Chloride of amyle .	$C^{10}H^{11}Chl$	10·375
Chloride of benzoen, .	$C^{[illegible]}H^3Chl^6+3(HChl)$	52·75
Chloride of benzole .	$C^{12}H^6+Chl^6$	36·5
Chloride of benzyle .	$C^{14}H^5O^2+Chl$	17·625
Chloride of chlorindopten	$C^{12}Chl^5+HO$	32·625
Chloride of methyle .	C^2H^3Chl	6·375
Chloride of salicyle .	$C^{14}H^5O^4Chl$	19·625
Chloride of strychnina .	$C^{22}H^{12}AzChl^2O^5$	33·75
Chloramital . .	$C^{10}H^{8\frac{1}{2}}Chl^{1\frac{1}{2}}O^2$	17·3125
Chloranthracinese .	$C^{30}H^{10}Chl^2$	32·75
Chlorindopten . .	$C^{16}H^4Chl^4O^2$	32·5
Chlorindoptic acid .	$C^{12}H^2Chl^3O+HO$	24·875?
Chlorindalmite . .	$C^{12}H^4Chl^3O^2$	25·
Chlorisatic acid . .	$C^{16}H^4ChlAzO^4+HO$	23·875
Chlorisatide . . .	$C^{16}H^5ChlAzO^4+S$	24·875
Chlorisatin . .	$C^{16}H^4ChlAzO^4$	22·75
Chlorobenzide . .	$C^{12}H^3Chl^3$	22·875
Chlorocuminol . .	$C^{20}H^{11}O^2+Chl$	22·875
Chlorohumic acid . .	$C^{32}H^{12}O^{16}Chl$	46·
Chloromenthen . .	$C^{20}H^{17}Chl$	21·625
Chloronaphthalic acid .	$C^{20}H^6ChlO^5+HO$	26·125
Chlorophenesic acid .	$C^{12}H^3Chl^3O+HO$	20·5
Chlorophenesic acid .	$C^{12}H^2Chl^3O+HO$	24·875
Chloroprotein . .	$C^{40}H^{31}Az^5O^{12}+Chl^3$	59·25
Chlorosalicin . .	$C^{42}H^{25}O^{22}Chl^4$	74·625
Chorosalicymide . .	$C^{42}H^{15}Az^2O^6Chl^3$	56·375
Chlorosulphuric acid .	SO^2Chl	8·5
Chlorovalerianic acid .	$C^{10}H^6Chl^4O^4$	30·25
Chloroxalic ether .	$C^2O^3+C^4Chl^5O$	31·
Chloroxamethan . .	$C^8H^2AzChl^5O^6$	36·5
Choleic . . .	$C^{41}H^{33}AzO^{12}+2(HO)$	50·875
Cholesteric . . .	$C^{13}H^{10}Az^{\frac{1}{2}}O^6$	17·875
Cholesterin . . .	$C^{76}H^{64}O^2$	67·
Choloidic . . .	$C^{32}H^{25}O^6$	33·125

	Composition.	Atomic weight.
Chondrin . . .	$10(C^{32}H^{26}Az^{4}O^{14}+S$	484·5
Chrysamminic acid .	$C^{15}HAz^{2}O^{12}$	26·875
Chrysanilic acid . .	$C^{28}H^{10}AzO^{5}$	30·75
Chrysene	$C^{12}H^{4}$	9·5
Chrysolepinic acid .	$C^{12}H^{2}Az^{3}O^{13}+HO$	28·625
Cinchovina . . .	$C^{46}H^{27}Az^{2}O^{8}$	49·375
Citric acid . . .	$C^{12}H^{5}O^{11}+3(HO)$	24·
Conicina . . .	$C^{16}H^{16}Az$	15·75
Creosote	$C^{6}H^{3}O$	5·875
Croconic acid . .	$C^{5}O^{4}$	7·75
Cubebin	$C^{34}H^{17}O^{10}$	37·625
Cumene	$C^{18}H^{12}$	15·
Cuminic acid . .	$C^{20}H^{11}O^{3}$	19·375
Cyanic acid . . .	$2(C^{2}Az)O+HO$	8·625
Cyanodide of benzyle .	$C^{14}H^{5}O^{2}+AzC^{2}$	16·375
Cyanodide of cacodyle .	$C^{4}H^{6}As^{2}+AzC^{2}$	16·5
Cyanogen . . .	$C^{2}Az$	3·25
Cyanuric acid . .	$6(C^{2}Az)O^{3}+3(HO)$	25·875
Cymene	$C^{20}H^{14}$	16·75
Cystic oxide . .	$C^{6}H^{6}AzO^{8}$	15.
D		
Dallecochin . .	$C^{30}H^{20}Az^{2}O^{10}$	38·5
Diabetes sugar . .	$C^{24}H^{24}O^{24}+4(HO)$	49·5
Dialuric acid . .	$C^{8}H^{7}Az^{3}O^{8}$	20·125
Dragon's blood . .	$C^{40}H^{21}O^{8}$	40·625
E		
Eblanin	$C^{21}H^{9}O^{4}$	20·875
Elaidic acid . .	$C^{70}H^{68}O^{8}$	69·
Elemi	$C^{40}H^{33}O$	35·125
Erythrilin . . .	$C^{22}H^{16}O^{6}$	24·5
Erythrin	$C^{8}H^{3}O^{2}$	8·375
Erythroleic acid . .	$C^{26}H^{22}O^{8}$	30·25
Eristhrolein . . .	$C^{26}H^{22}O^{4}$	26·25
Erythrolitmin . .	$C^{26}H^{22}O^{12}$	34·25
Ethal	$C^{16}H^{17}O$	15·125
Ether	$C^{4}H^{5}O$	4·625
Ethionic acid . .	$S^{2}O^{5}+C^{4}H^{4}O+O$	14·625
Ethyle	$C^{4}H^{5}$	3·625
Euchronic acid . .	$C^{12}AzO^{6}$	16·75
Euphorbium resin .	$C^{40}H^{31}O^{6}$	39·875
Eupion	$C^{9}H^{10}$	9·
F		
Fibrin	$10(C^{40}H^{31}Az^{5}O^{2})+Ph+S$	550·25
Fibrin of silk . .	$C^{38}H^{31}Az^{6}O^{17}$	59·875
Fichtelite . . .	$C^{4}H^{3}$	3·375
Fluoride of cacodyle .	$C^{4}H^{6}As^{6}Fl$	14·5

	Composition.	Atomic weight.
Formethylite . .	$C^8H^{10}O^6$	13·25
Formic acid . . .	C^2HO^3	4·625
Formic ether . .	$C^2HO^3+C^4H^5O$	9·25
Formobenzoilic acid .	$C^{14}H^5O^2+C^2HO^3+Aq$	17·875
Fossil wax of Gallicia .	C^xH^x	
Fulminic acid . .	$4(C^2Az)O^2+2(HO)$	17·25
Fumaramide . .	$C^4HO^2+AzH^2$	7·125
Fumaric acid . .	C^4HO^3	6·125
G		
Gallic acid	C^7HO^3	8·375
Gamboge (resin of) .	$C^{82}H^5O^{20}$	86·25
Gelatin from silk . .	$C^{19}H^{15}Az^3O^7$	28·375
Glucinic acid . .	$C^8H^5O^5$	11·625
Guaiacum resin . .	$C^{40}H^{23}O^{10}$	42·875
Garanina . . .	$C^{12}H^6Az^3O^3$	18·
Guyoquillite . .	$C^{20}H^{13}O^3$	19·625
H		
Harmalina . . .	$C^{24}H^{12}Az^2+HO$	24·125
Hatchettine . .	C^xH^x	
Helenin . . .	$C^{15}H^{10}O^2$	14·5
Hematosin . . .	$C^{44}H^{22}Az^3O^6$	50·5
Hippuric acid . .	$C^{18}H^8AzO^5$	21·25
Hippuric ether . .	$C^{18}H^8AzO^5+C^4H^5O$	25·875
Humic acid . . .	$C^{40}H^{12}O^{12}$	43·5
Humin . . .	$C^{40}H^{15}O^{15}$	46·875
Hydrate of phenyle .	$C^{12}H^5O+HO$	11·75
Hydrated oxide of amyle	$C^{10}H^{11}O+HO$	11·
Hydret of azobenzoilin	$C^{42}H^{18}Az^2$	37·25
Hydret of benzoilin .	$C^{42}H^{18}O^6$	39·75
	$C^{14}H^6O^2$	13·25
Hydret of benzyle .	$C^{14}H^6O^2$	13·25
Hydret of sulphazobenzoil	$C^{126}H^{54}Az^2S^{12}$	130·75
Hydret of sulphobenzoil	$C^{14}H^6S^2$	15·25
Hydrobenzamide . .	$C^{22}H^{18}Az^2$	37·25
Hydrochlorate of chloride of amyle . .	$C^{10}H^3Chl^9$	48·375
Hydromelonic acid .	$C^6HAz^4+4(HO)$	16·125
Hydrotelluric ether .	$C^4H^5Fl^2$	11·625
Hydrous aspartic acid .	$C^8H^5AzO^6+2(HO)$	16·625
Hydrous citric acid .	$C^{12}H^5O^{11}+3(HO)$	24·
Hydrous gallic acid . .	$C^7HO^3+2(HO)$	10·625
Hydrous mellitic acid .	C^4H^3+HO	7·125
Hydrous mucic acid .	$C^{12}H^8O^{14}+2(HO)$	26·25
Hydrous subchloride of cacodyle . .	$C^4H^6As^2+Chl+HO$	18·875
Hydrous tannic acid .	$C^{18}H^5O^9+3(HO)$	26·5
Hydrous tartaric acid .	$C^8H^4O^{10}+2(HO)$	18·75

	Composition.	Atomic weight.
Hypobenzylic acid	$C^{14}H^{5}O^{1\frac{1}{2}}$	12·625
Hypo-sulpho benzydic acid	$C^{12}H^{5}O^{5}S^{2}+HO$	20·125
I		
Jalap resin	$C^{40}H^{34}O^{20}$	54·25
Idrialin	$C^{15}H^{5}$	11·875
Jervina	$C^{60}H^{45}Az^{2}O^{5}$	59·125
Indigogen	$C^{16}H^{6}AzO^{2}$	16·5
Indigotic acid	$C^{14}H^{4}AzO^{9}$	21·75
Indigotin	$C^{16}H^{5}AzO^{2}$	16·375
Inulin	$C^{24}H^{21}O^{21}$	41·625
Iodide of amyle	$C^{10}H^{11}O+Io$	25·625
Iodide of benzyle	$C^{14}H^{5}O^{2}+Io$	28·875
Iodide of cacodyle	$C^{4}H^{6}As^{2}+Io$	29·
Iodosalicylic acid	$C^{14}H^{5}O^{4}+Io$	30·875
Isatic acid	$C^{16}H^{5}AzO^{4}+2(HO)$	20·625
Isatide	$C^{16}H^{6}AzO^{4}$	18·5
Isatin	$C^{16}H^{5}AzO^{4}$	18·375
Itaconic acid	$C^{5}H^{2}O^{3}+HO$	8·125
K		
Kalisaccharic acid	$C^{18}H^{15}O^{15}$	30·375
Kinic acid	$C^{14}H^{8}O^{8}$	19·5
L		
Labdanum	$C^{40}H^{33}O^{7}$	41·125
Lactic acid	$C^{6}H^{3}O^{4}$	8·875
Lecanorin	$C^{18}H^{8}O^{8}$	22·5
Lignin	$C^{12}H^{9}O^{9}$	19·125
Lipic acid	$C^{5}H^{3}O^{4}+HO$	9·25
Lithofellic acid	$C^{42}H^{38}O^{8}$	44·25
M		
Malic acid	$C^{8}H^{4}O^{8}$	14·5
Mannite	$C^{24}H^{28}O^{24}$	45·5
Margaric acid	$C^{34}H^{33}O^{3}+HO$	33·75
Margarin	$C^{33}H^{33}O$	29·875
Mastich resin, *a*	$C^{40}H^{31}O^{4}$	37·875
Mastich resin, *b*	$C^{40}H^{31}O^{2}$	35·875
Meconic acid	$C^{14}HO^{11}+3(HO)$	25·
Melanic acid	$C^{10}H^{4}O^{5}$	13·
Melanochin	$C^{24}H^{18}Az^{1}O^{12}$	36·375
Mellitic acid	$C^{4}O^{3}$	6·
Menthene	$C^{21}H^{18}$	18·
Mercuriobromide of oxide of cacodyle	$C^{4}H^{6}As^{2}O+Hg^{2}Br^{2}$	59·25
Mercuriochloride of oxide of cacodyle	$C^{4}H^{6}As^{2}O+Hg^{2}Chl^{2}$	48·25
Mesite	$C^{6}H^{7}O^{3}$	8·375

	Composition.	Atomic weight.
Mesoxalic acid	C^3O^4	6·25
Metameconic acid	$C^{12}H^2O^8+2(HO)$	17·25
Metacinnamein	$C^{18}H^8O^2$	16·5
Metanaphthalin	$C^{28}H^{12}$	22·5
Methylal	$C^{12}H^8O^4$	14·
Methyle	C^2H^3	1·875
Middletonite	$C^{20}H^{11}O$	17·375
Micomelic acid	$C^8H^5Az^4O^5$	18·625
Morphina	$C^{35}H^{20}AzO^6$	36·5
Mucic acid	$C^{12}H^8O^{14}$	24·
Murexane	$C^6H^4Az^2O^5$	13·5
Murexide	$C^{12}H^6Az^5O^8$	26·5
N		
Naphtha	$C^{14}H^{13}$	12·125
Naphthalic acid	$C^{16}H^4O^6$	18·5
Naphthene	$C^{16}H^{16}$	14·
Naphthol	$C^{24}H^{20}$	20·5
Naphtholin	$C^{28}H^{11}$	22·375
Narcotina	$C^{44}H^{23}AzO^{15}$	50·625
Nicotina	$C^{10}H^8Az$	10·375
Nigric acid	$C^{14}H^7O^7$	18·375
Nitro-anisic acid	$C^{16}H^6O^5+AzO^5$	25·
Nitro-aniside	$C^{20}H^{10}Az^2O^{10}$	29·75
Nitro-benzide	$C^{12}H^5+AzO^4$	15·375
Nitrobenzoic acid	$C^{14}H^5AzO^8$	20·875
Nitronaphthalase	$C^{10}H^7AzO^4$	14·125
Nitronaphthalese	$C^{20}H^6Az^2O^8$	27·25
Nitronaphthalic acid	$C^{12}H^5AzO^{12}$	23·375
Nitronaphthalise	$C^{20}H^5Az^3O^{12}$	32·875
Nitrophenesic acid	$C^{12}H^3(AzO^4)^2O+HO$	23·
Nitrophenisic acid	$C^{12}H^2(AzO^4)^3O+HO$	28·625
Nitrophloretic acid	$C^{30}H^{12}AzO^{15}$	40·75
Nitrosalicylic acid	$C^{14}H^5O^4+AzO^4$	20·875
O		
Oil of anise	$C^{20}H^{12}O^2$	18·5
Oil of ants	$C^5H^2O^2$	6·
Oil of Artemisia sanctonica	$C^{18}H^{15}O^2$	17·375
Oil of asarum	C^7H^5O	6·875
Oil of assafœtida	$C^{50}H^{45}O^4S^5$	58·125
	$C^{95}H^{89}O^{20}S^{10}$	22·375
Oil of bitter almonds	$C^{14}H^6O^2$	13·25
Oil of bergamotte	$C^{10}H^8$	8·5
Oil of cajeput	$C^{10}H^9O$	9·625
Oil of camphor	$C^{14}H^{11}O$	12·875
Oil of cascarilla	$C^{24}H^{18}O$	21·25
	$C^{14}H^{11}O$	12·875
Oil of cedar	$C^{32}H^{25}O^2$	29·25

	Composition.	Atomic weight.
Oil of cinnamon	$C^{20}H^{11}O^{2}$	18·375
Oil of cloves	$C^{24}H^{15}O^{5}$	24·875
Oil of copaiva	$C^{10}H^{8}$	8·5
Oil of cubebs	$C^{15}H^{12}$	12·75
Oil of elemi	$C^{10}H^{8}$	8·5
Oil of fennel	$C^{15}H^{12}$	12·75
Oil of hyssop	$C^{60}H^{47}O$	51·875
Oil of juniper	$C^{15}H^{12}$	12·75
Oil of lavender	$C^{12}H^{10}O$	11·25
Oil of laurel	$C^{20}H^{16}$	17·
Oil of lemons	$C^{10}H^{8}$	8·5
Oil of mace	$C^{16}H^{13}O$	14·625
Oil of marjoram	$C^{50}H^{40}O$	43·5
Oil of mustard	$C^{41}H^{25}Az^{4}S^{10}$	60·875
Oil of olibanum	$C^{35}H^{28}O$	30·75
Oil of orange flowers	$C^{10}H^{8}$	8·5
Oil of orange peel	$C^{10}H^{8}$	8·5
Oil of parsley	$C^{10}H^{8}$	8·5
Oil of pennyroyal	$C^{15}H^{14}O^{2}$	15·
Oil of pepper	$C^{13}H^{10}$	11·
Oil of peppermint	$C^{12}H^{10}O$ / $C^{25}H^{22}O^{2}$	11·25 / 23·5
Oil of rosemary	$C^{45}H^{38}O^{2}$	40·5
Oil of roses	$C^{23}H^{23}O^{3}$	23.125
Oil of rue	$C^{28}H^{28}O^{3}$	27·5
Oil of sabine	$C^{20}H^{16}$	17·
Oil of Spiræa ulmaria	$C^{11}H^{5}O^{3}$	10·875
Oil of turpentine	$C^{20}H^{16}$	17·
Oenanthylic acid	$C^{14}H^{13}O^{3}$	15·125
Oleic acid	$C^{44}H^{39}O^{4}+HO$	43·
Orcein, *α*	$C^{18}H^{10}+AzO^{5}$	21·5
Orcein, *β*	$C^{18}H^{10}AzO^{8}$	24·5
Orcin	$C^{16}H^{6}O^{2}$	14·75
Oxalate of oxide of methyle	$C^{2}O^{3}+C^{2}H^{3}O$	7·375
Oxalhydric acid	$C^{12}H^{5}O^{11}$	20·625
Oxalic acid	$C^{2}O^{3}$	4·5
Oxaluric acid	$C^{6}H^{4}Az^{2}C^{8}$	16·5
Oxiodide of cacodyle	$C^{4}H^{6}As^{2}O+3(C^{4}H^{6}AsIo)$	101·25
Oxide of amyle	$C^{10}H^{11}O$	9·875
Oxide of benzyle	$C^{14}H^{5}O$	12·125
Oxide of cacodyle	$C^{4}H^{6}Az^{2}O$	14·25
Oxide of methyle	$C^{2}H^{3}O$	2·875
Oxybromide of cacodyle	$C^{4}H^{6}As^{2}O+3(C^{4}H^{6}As^{2}Br)$	84·
Oxychloride of cacodyle	$C^{4}H^{6}As^{2}O+3(C^{4}H^{6}As^{2}Chl)$	67·5
Oxyprotein	$C^{40}H^{31}Az^{5}O^{15}+HO$	58·75
Ozocerate	$C^{x}H^{x}$	
P		
Palminic acid	$C^{66}H^{62}O^{7}+HO$	65·5

	Composition.	Atomic weight.
Parabanic acid . .	$C^6H^2Az^2O^6$	14·25
Paraffin . . .	$C^{20}H^{21}$	17·625
Paramide . . .	C^8HAzO^4	11·875
Paranaphthalin . .	$C^{30}H^{12}$	24·
Paratartaric acid .	$C^8H^4O^{10}+1\frac{1}{2}(HO)$	18·1875
Peat, resin, *a* . .	$C^{50}H^{40}O^9$	51·5
Peat, resin, *b* . .	$C^{77}H^{67}O^9$	75·125
Peat, resin, *c* . .	$C^{104}H^{94}O^9$	98·75
Peat, resin, *d* . .	$C^{131}H^{121}O^9$	122·375
Peat, resin, *α* . .	$C^{35}H^{23}O^5$	34·75
Peat amma resin . .	$C^{90}H^{84}O^6$	84·
Pectic acid . . .	$C^{11}H^7O^{10}$	19·125
Perchloric ether . .	$ChlO^7+C^4H^5O$	16·125
Peristerin . . .	C^4H^3O	4·375
Petrolene . . .	$C^{20}H^{16}$	17·
Peruvin . . .	$C^{18}H^{12}O^2$	17.
Phene . . .	C^{1}[illegible]H^6	9·75
Phenyle . . .	$C^{12}H^5O$	10·625
Phloretin . . .	$C^{42}H^{21}O^{14}$	48·125
Phlorizein . . .	$C^{42}H^{30}O^{24}+Az^2O^3$	65·75
Phlorizin . . .	$C^{42}H^{21}O^{16}$	50·125
Phosphoric acid . .	Ph^2O^5	9·
Pimaric acid . .	$C^{20}H^{15}O^2$	18·875
Pimelic acid . .	$C^7H^5O^3+HO$	10·
Piperina . . .	$C^{34}H^{10}AzO^6$	35·625
Polychrom . . .	$C^8H^{4\frac{1}{2}}O^5$	11·5625
Polygalic acid . .	$C^9H^8O^6$	15·75
Potassio cuminol . .	$C^{20}H^{11}O+K$	23·375
Protein . . .	$C^{48}H^{36}Az^6O^{14}$	65·
Protonitro benzoene .	$AzO^4+C^{14}H^7$	17·125
Pseudacetic acid . .		9·15
Pyrene . . .	$C^{10}H^4$	8·
Pyrocatechin . .	C^6H^2O+HO	6·875
Pyromaric acid . .	$C^{20}H^{15}O$	18·875
Pyromeconic acid .	$C^{10}H^3O^5+H$	14·
Pyruric acid . .	$C^4H^8AzO^5$	10·75 ?
Q		
Quercitric acid . .	$C^{16}H^9O^{10}$	23·125
Quinina . . .	$C^{40}H^{24}Az^2O^4$	40·5
R		
Resin of indigo . .	$C^{40}H^{16}Chl^4O^{10}$	61·75
Resin of tolu . .	$C^{18}H^{10}O^5$	19.75
Retinaphtha . .	$C^{14}H^8$	11·5
Retinasphalt . .	C^7H^5O	6·875
Retinol . . .	$C^{32}H^{16}$	26
Retinyle . . .	$C^{18}H^{12}$	15
Rhodizonic acid . .	C^3O^5	7·25 ?

	Composition.	Atomic weight.
Rhubarbaric acid . .	$C^{35}H^{19}O^{19}$	47·625
Rusiochin . . .	$C^{24}H^{30}Az^{2}O^{16}$	41.25
S		
Saccharic acid . .	$C^{12}H^{5}O^{11}$	20·625
Sagapenum . . .	$C^{40}H^{29}O^{9}$	42·625
Salicin . . .	$C^{42}H^{19}O^{22}$	55·875
Salicylic acid . .	$C^{14}H^{5}O^{5}$	16·125
Salicyle . . .	$C^{14}H^{5}O^{4}$	15.125
Salicyle, hydret of .	$C^{14}H^{6}O^{4}$	15·25
Salicon . . .	$C^{42}H^{25}O^{7}$	41·625
Salicylimide . .	$C^{42}H^{18}Az^{2}O^{6}$	43·25
Saliretin . . .	$C^{30}H^{15}O^{7}+HO$	32·5
Sandarach, resin, *a* .	$C^{40}H^{31}O^{5}$	38·875
Sandarach, resin, *b* .	$C^{40}H^{31}O^{6}$	39·875
Sandarach, resin, *c* .	$C^{40}H^{30}O^{6}$	39·75
Scammony resin . .	$C^{40}H^{33}O^{20}$	54·25
Sebacic acid . .	$C^{10}H^{8}O^{3}$	11.5
Seleniet of cacodyle .	$C^{4}H^{6}As^{2}+Se$	17·75
Semichloret of ether .	$C^{4}H^{4}ChlO$	9
Sericic acid . .	$C^{28}H^{28}O^{4}$	28·5
Sinapolin . . .	$C^{28}H^{25}Az^{4}O^{4}$	35.125
Spanolitmin . .	$C^{18}H^{7}O^{16}$	30·375
Starch . . .	$C^{12}H^{9}O^{9}$	19·125
Stearic acid . .	$C^{68}H^{66}O^{5}+2(HO)$	66·5
Stearopten of oil of bergamotte . . .	$C^{3}HO$	3.375
Stearopten of oil of lemons	$C^{2}H^{2}O$	2·75
Stearopten of oil of mace	$C^{16}H^{16}O^{5}$	19
Stearopten of oil of marjoram . . .	$C^{14}H^{15}O^{5}$	17·375
Stearopten of oil of peppermint . . .	$C^{21}H^{20}O^{2}$	20·25
Strychnina . . .	$C^{42}H^{22}Az^{2}O^{4}$	41.75
Styracin . . .	$C^{18}H^{11}O^{2}$	21·375
Styrole . . .	$C^{12}H^{6}$	9·75
Suberic acid . .	$C^{8}H^{6}O^{3}+HO$	10·875
Succinic. . . .	$C^{4}H^{2}O^{3}+HO$	7·375
Succino-sulphuric acid .	$C^{8}H^{4}O^{6}+2(HO)+2(SO^{3})$	24·75
Sugar, common . .	$C^{24}H^{18}O^{18}$	38·25
Sugar, grape . .	$C^{24}H^{24}O^{24}+4(HO)$	49·5
Sugar, jelly . .	$C^{16}H^{18}Az^{4}O^{14}$	35·25
Sugar of milk . .	$C^{24}H^{20}O^{20}+2(HO)$	42·75
Sulphamilic acid . .	$SO^{3}+C^{10}H^{11}O+HO$	9
Sulphethyl-sulphuric acid	$C^{4}H^{5}O^{4}S^{2}$	11·625
Sulphindilic acid . .	$C^{16}H^{4}AzO+SO^{3}$	20.25
Sulphisatin . . .	$C^{16}H^{5}AzO^{2}+S^{3}$	22·5
Sulpho-amylate of barytes	$\{(SO^{3}+C^{10}H^{11}O)+(SO^{3}+BaO)+HO\}$	23·5

	Composition.	Atomic weight.
Sulphobenzide	$C^{12}H^{5}O^{2}S$	15·125
Sulphobenzoenic acid	$C^{14}H^{10}+S^{2}O^{5}$	20·75
Sulphobenzoic acid	$C^{14}H^{4}O^{3}+S^{2}O^{5}+2Aq$	24·375
Sulphobiproteic acid	$\left\{ 2(C^{40}H^{31}Az^{5}O^{12})+SO^{3} +2(HO) \right.$	116·5
Sulphocumenic acid	$C^{18}H^{12}+S^{2}O^{5}$	29·
Sulphohelenic acid	$C^{15}H^{10}O^{2}+SO^{3}+HO$	20·625
Sulphohydret of azobenzoil	$C^{42}H^{18}Az^{2}S^{3}$	43·25
Sulphophenic acid	$C^{12}H^{5}O+2(SO^{3})+HO$	21·75
Sulphoproteic acid	$C^{40}H^{31}Az^{5}O^{12}+SO^{3}$	59·625
Sulphopurpuric acid	$C^{32}H^{10}Az^{2}O^{4}+2(SO^{3})$	42·75
Sulphoretenilic acid	$C^{18}H^{12}+S^{2}O^{5}$	24·
Sulphuret of benzyle	$C^{14}H^{5}O^{2}+S$	15·125
Sulphuret of cacodyle	$C^{4}H^{6}As^{2}+S$	15·25
T		
Tannin	$C^{18}H^{5}O^{9}$	23·125
Tartaric acid	$C^{8}H^{4}O^{10}$	16·5
Tartralic acid	$C^{8}H^{4}O^{10}+1\frac{1}{2}(HO)$	18·1875
Tartrelic acid	$C^{8}H^{4}O^{10}+HO$	17·625
Terethrin	$C^{2}H^{10}O^{19}$	36·75
Theobromin	$C^{9}H^{5}Az^{3}O^{2}$	14·625
Theina	$C^{12}H^{6}Az^{3}O^{3}$	18·
Thionuric acid	$C^{8}H^{5}Az^{3}O^{6}+2(SO^{3})$	27·875
Tolene	$C^{15}H^{10}$	11·
U V		
Valerianic ether	$C^{10}H^{9}O^{3}+C^{4}H^{5}O$	16·25
Veratric acid	$C^{18}H^{10}O^{8}$	22·75
Ulmic acid	$C^{40}H^{14}O^{12}$	43·75
Ulmin	$C^{40}H^{16}O^{4}$	36·
Uramile	$C^{8}H^{5}Az^{3}O^{6}$	17·875
Uramilic acid	$C^{16}H^{10}Az^{5}O^{15}$	37·
Urea	$C^{2}H^{4}Az^{2}O^{2}$	7·5
Uric acid	$C^{9}Az^{2}O^{4}+C^{2}H^{4}Az^{2}O^{2}$	21·75
Uric oxide	$C^{5}H^{2}Az^{2}O^{2}$	9·5
X		
Xanthic oxide	$C^{5}H^{2}Az^{2}O^{2}$	9·5
Xanthoproteic acid	$C^{34}H^{24}Az^{4}O^{14}+2(HO)$	52·
Xylite	$C^{4}H^{5}O^{2}$	5·625

INDEX.

PRINTED BY JOHN STARK, OLD ASSEMBLY CLOSE, EDINBURGH.


C191